RECORD-BREAKING TIDAL FLOODS ARE COMING → P19

WHAT HAPPENS WHEN TWO BLACK HOLES COLLIDE? → P34

I BOUGHT A GHOST TOWN AND NOW I HAVE TO RESTORE IT → P56

HOW TO BUILD A BACKYARD GREENHOUSE → P84

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P42

POPULAR MECHANICS

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POPULAR MECHANICS

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ON THE COVER: RICH REBUILDS V-8 TESLA MODEL S, PHOTOGRAPHED BY CHRISTOPHER CHURCHILL; COURTESY IMAGE (HYPERVOLT GO 2); ON THIS PAGE: HENRY HUNG (GREENHOUSE)

SIGNING OFF

PHOTOGRAPHY: STIV SAMUEL

THE PROCESS OF PUTTING together this issue of Popular Mechanics and sending it off to the printer has been bittersweet.

Since being appointed editor of this fine publication, back in 2018, I've thoroughly enjoyed creating every single issue. I've learnt a great deal, through the interesting array of stories, features and articles that we've run; I got to know many of our loyal advertising clients, as well as you, our cherished readers. I've had the privilege of working with a devoted team of co-workers and contributors, who've always strived to create the best product possible. And I've been lucky enough to drive and test some amazing vehicles along the way, and try out some brilliant gadgets and tech.

The reason why this production cycle in particular has been bittersweet, is because this is the very last issue of Popular Mechanics (South Africa edition) that we will be publishing. Significant increases in costs in recent times have had knock-on effects, and the result is that it's no longer viable to create the magazine.

Still, I like to think that we've gone out with a bang, and that you'll thoroughly enjoy every feature in this issue.

If you're an active subscriber, and haven't yet heard from our subscription department, please get in touch with them to make arrangements for a refund. Drop them an email on *subscriptions@habarimedia.com*, or call 087 550 0329.

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See you down the road…

Mark

MARK SAMUEL
Editor

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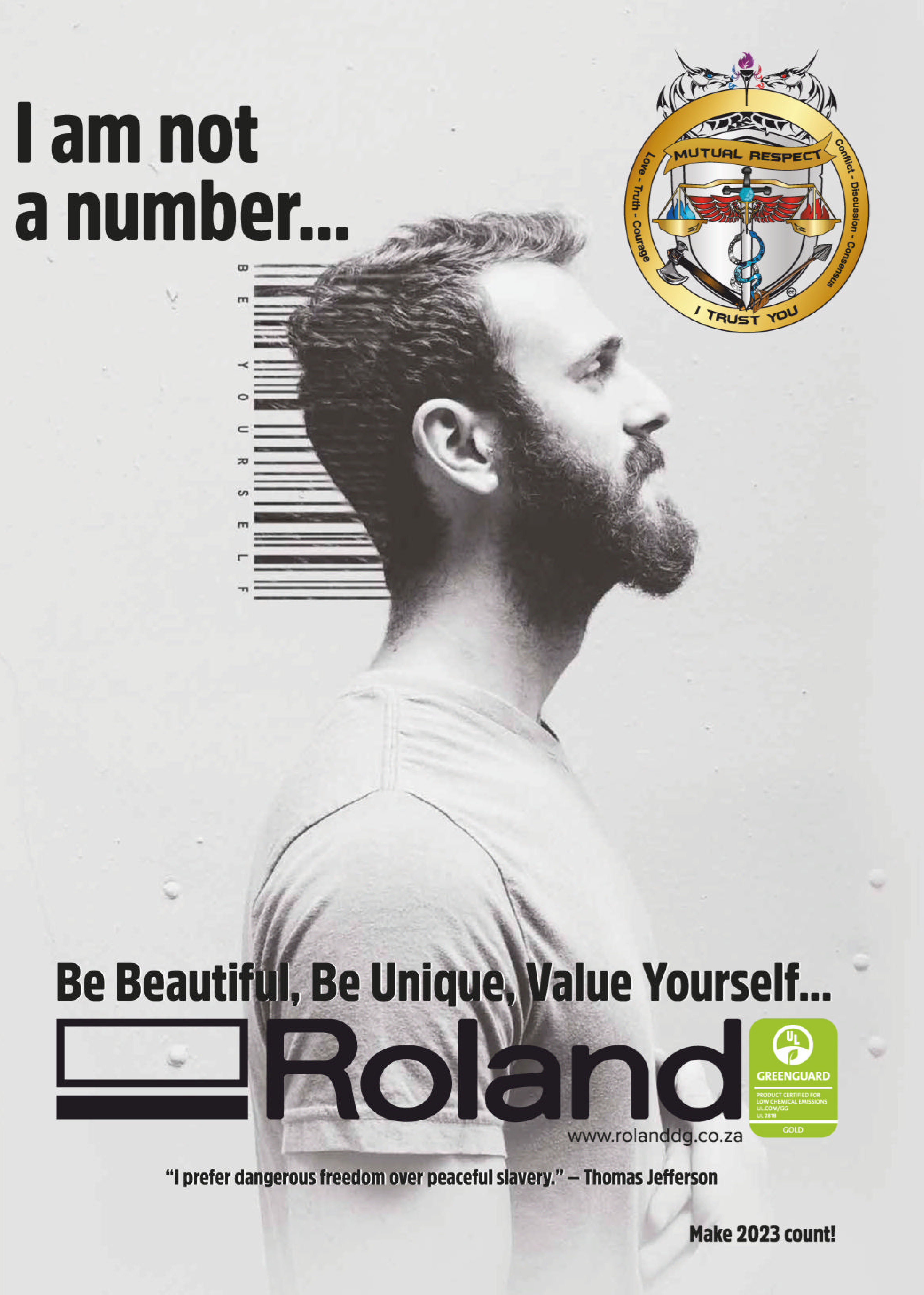
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WINNING LETTER

Power trip

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Solid-state lithium batteries can last 25 years and charge an electric vehicle in minutes.
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'We could reset our expectations for battery life. It could be as long as 25 years or even half a century.'

I thoroughly enjoyed reading the most recent November/December issue. I was particularly impressed with the diverse mix of features, from the 'How your world works' short articles up front (the report on autonomous drones felt all too relevant, with the recent developments in the Russia–Ukraine conflict), to the final instalment in the woodworking tutorial. I've followed Tobias' series of articles in the past few years with keen interest. He's clearly a highly skilled woodworker, and, being an enthusiastic novice in that realm, I've learnt so much from him.

But it was the story on breakthrough battery technology, on page 42, that really caught my eye. It seems we're making great strides when it comes to the technology that creates power from sustainable sources, however it's our ability to store that energy efficiently that's lagging behind. Everyone who's reading this magazine in South Africa can relate, I'm sure. So many of us are seeking efficient and cost-effective ways to store power to see us through load-shedding events – batteries that recharge quickly when the power is on but that also have longer lifespans. That article really gave me a sense of renewed optimism that *sooner* rather than *later* highly efficient 'solid state' batteries will be more widely available. Can you imagine owning a bank of batteries that not only recharges extremely quickly, but that holds its charge for thousands upon thousands of cycles? I guess the real question, is, how much will this sort of power-storage solution cost the consumer? Time will tell. In the meantime I'll have to make do with my old-school deep-cycle battery and inverter system. So far, it's been doing the job. Long may that battery last!

ALAN BAUER

Thanks for your letter, Alan. That long-read feature about the advancement of battery technology certainly piqued our interest, too! After 15+ years of load-shedding, I think we South Africans are always on the lookout for efficient battery storage systems and other power solutions. I've already had one deep-cycle battery die on me, and the replacement didn't come cheap.

For sharing your thoughts, you've won this issue's readers' letters prize.

– Mark, Editor

The writer of this issue's winning letter has won a 101-piece KT2575 drive set from Tork Craft valued at R574, sponsored by *vermontsales.co.za*.

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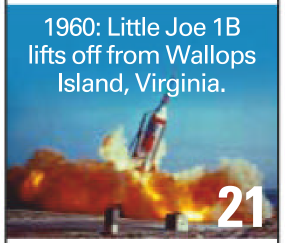
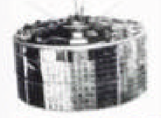
JANUARY 2023

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
New Year's Day **1**	Public holiday **2**	1815: A secret defensive alliance is formed by Austria, Britain and France, against Prussia and Russia. **3**	**4**	1950: 19 people are killed in the Sverdlovsk air disaster, including most members of the Soviet Air Force ice hockey team. **5**	**6**	 1785: Jeffries and Blanchard cross from Dover to Calais in a gas balloon. **7**
8	1913: Richard Nixon, 37th president of the United States, is born in California. He died, aged 81, in New York City. **9**	**10**	 1908: The Grand Canyon is declared a national monument. **11**	**12**	1968: American singer Johnny Cash performs to an audience of more than 2 000 inmates at Folsom Prison in California. **13**	**14**
2005: The Joe Slovo informal settlement outside Cape Town is ravaged by a runaway fire. **15**	**16**	1931: Actor James Earl Jones is born. Among many other roles, he was the voice of Darth Vader in the *Star Wars* franchise. **17**	**18**	1983: The Apple Lisa, a desktop computer with a graphical user interface and mouse, developed by Apple, is released. **19**	**20**	 1960: Little Joe 1B lifts off from Wallops Island, Virginia. **21**
22	2018: Hugh Masekela, one of South Africa's most famous jazz musicians, dies in Johannesburg. **23**	**24**	1945: Flouride is introduced into the drinking water of Grand Rapids, Michigan, to help fight tooth decay. **25**	**26**	1961: After a snorkel malfunctions and floods the boat, a Soviet diesel-electric S-80 submarine sinks. **27**	**28**
1980: The Rubik's Cube is debuted in London. **29**	**30**	2020: Three years after the country voted for 'Brexit', the UK formally leaves the European Union. **31**				

FEBRUARY 2023

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
			1981: Graeme Smith, former South African international cricket captain, is born in Johannesburg. **1**	**2**	1966: The US launches its first weather satellite.  **3**	**4**
2009: The journal *Nature* publishes a report about the discovery of a 13 m-long snake, that lived around 60 million years ago. **5**	**6**	1999: After the death of his father King Hussein, Crown Prince Abdullah becomes the king of Jordan. **7**	**8**	2001: The submarine USS *Greeneville* collides with Japanese fishery high-school training ship *Ehime Maru*. **9**	**10**	1970: Japan launches *Ohsumi*, making it the fourth country to put a satellite into orbit. **11**
12	2021: Winter storm Uri causes widespread electricity blackouts in Texas. **13**	**14**	 1898: The USS *Maine* explodes in Havana harbour, Cuba. **15**	**16**	1801: A tie in the Electoral College is resolved, and Thomas Jefferson is elected as President of the United States. **17**	**18**
1990: Nelson Mandela is issued with his first passport, eight days after being released from prison. **19**	**20**	1958: The USS *Gudgeon* returns to Pearl Harbour, becoming the first US submarine to circumnavigate the globe. **21**	**22**	1893: Rudolf Diesel receives a German patent for his invention of the 'diesel' engine. **23**	**24**	1895: Groenkloof Nature Reserve, the first game sanctuary in Africa, is proclaimed by Paul Kruger. **25**
26	 1964: Italy requests help with stabilising the Tower of Pisa. **27**	**28**				

TEXT: MARK SAMUEL; PHOTOGRAPHY: NASA, NOAA PHOTO LIBRARY, PUBLIC DOMAIN, UNSPLASH, US NAVY

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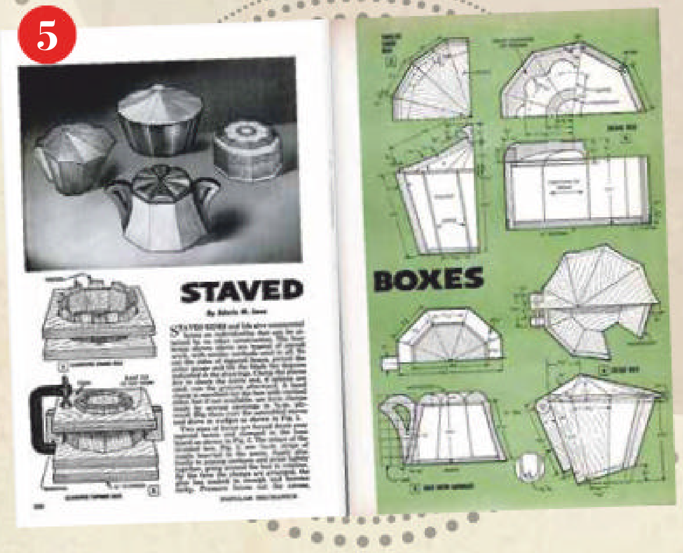
4 new shop tools to make
Modern hutch you can build
PLUS: Play cubes, coffee table ...and more!
THE MYSTERY PLANE THAT ALMOST KILLED HOWARD HUGHES
HALF-SIZE P-47
1

New look for an old refrigerator

1 JANUARY 1981

▸ 21 Exciting New Sports Planes You Can Build

The cover of this issue, a little more than 40 years ago, showed an eye-catching half-size replica of a WWII P-47 Thunderbolt. In addition to describing the build project of this plane, the accompanying article gave a rundown of 20 more aeroplane models that you could build yourself, including other warbird replicas, and unconventional-looking ultra-lights, some of which 'you can launch with your feet (but nobody ever does)'.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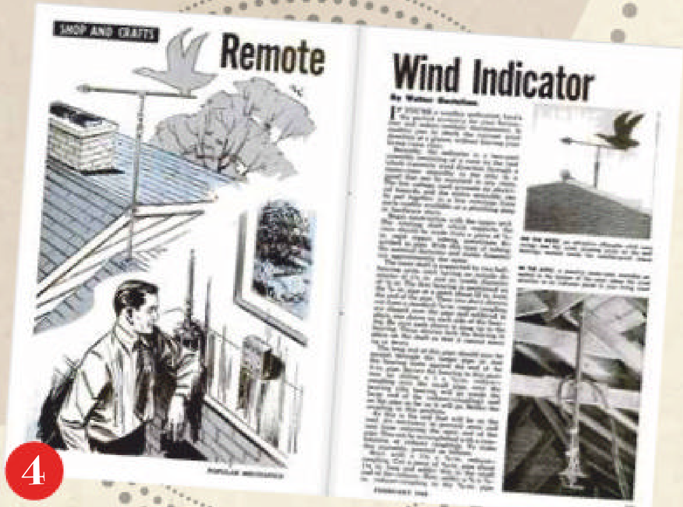
SHOP AND CRAFTS

Remote Wind Indicator

2 FEBRUARY 1978

▸ New Look at an Old Ditch

This story revealed some astonishing facts about the Panama Canal, such as, 'About 500 men died for every mile of the 50-mile-long construction'. The report said plans were being set in motion to build an additional canal route through Panama, that wouldn't require ships to use a lock system to get through... To date, this project has never been undertaken.

3 JANUARY 1974

▸ New Look for an Old Refrigerator

This short how-to DIY feature, including photos and a drawing with measurements, was about giving a 12 year-old fridge a new and updated look, including 'dark oak panels framed with satin-finish aluminium'. We doubt this would suit many kitchens today, but the concept of updating a fridge is certainly quite novel!

4 FEBRUARY 1965

▸ Remote Wind Indicator

This multi-page article provided detailed insight into how to build and erect a wind-direction indicator on your house's roof, so you could 'check the current wind direction at a glance, without leaving your living-room chair'. Step by step instructions and comprehensive drawings made this project doable for anyone with a fair degree of technical know-how.

5 JANUARY 1957

▸ Staved Boxes

This woodworking write-up gave specialised advice on how to create staved boxes, an intricate ornamental look which no other construction methods can achieve. The report highlighted the jigs and tools needed for this type of work, and divided the process into achievable steps. Mahogany wedges added a unique look to the lid. **PM**

TEXT: MARK SAMUEL; PHOTOGRAPHY: POPULAR MECHANICS ARCHIVES

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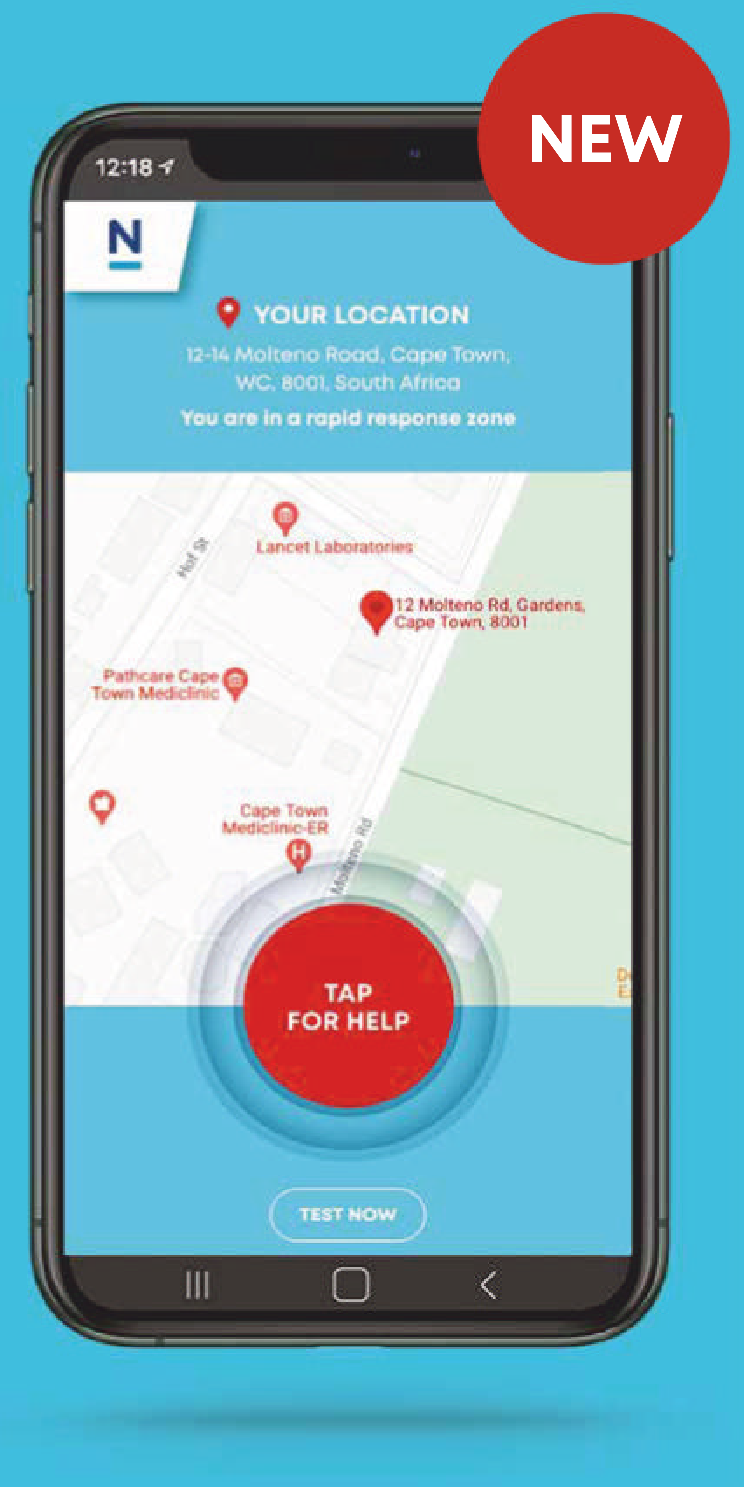
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BOOK REVIEW

/ BY TIANA CLINE /

Flying cars and robot butlers!

The Skeptics' Guide to the Future is a high-tech road map that redefines what it means to be human, based on science, not imagination.

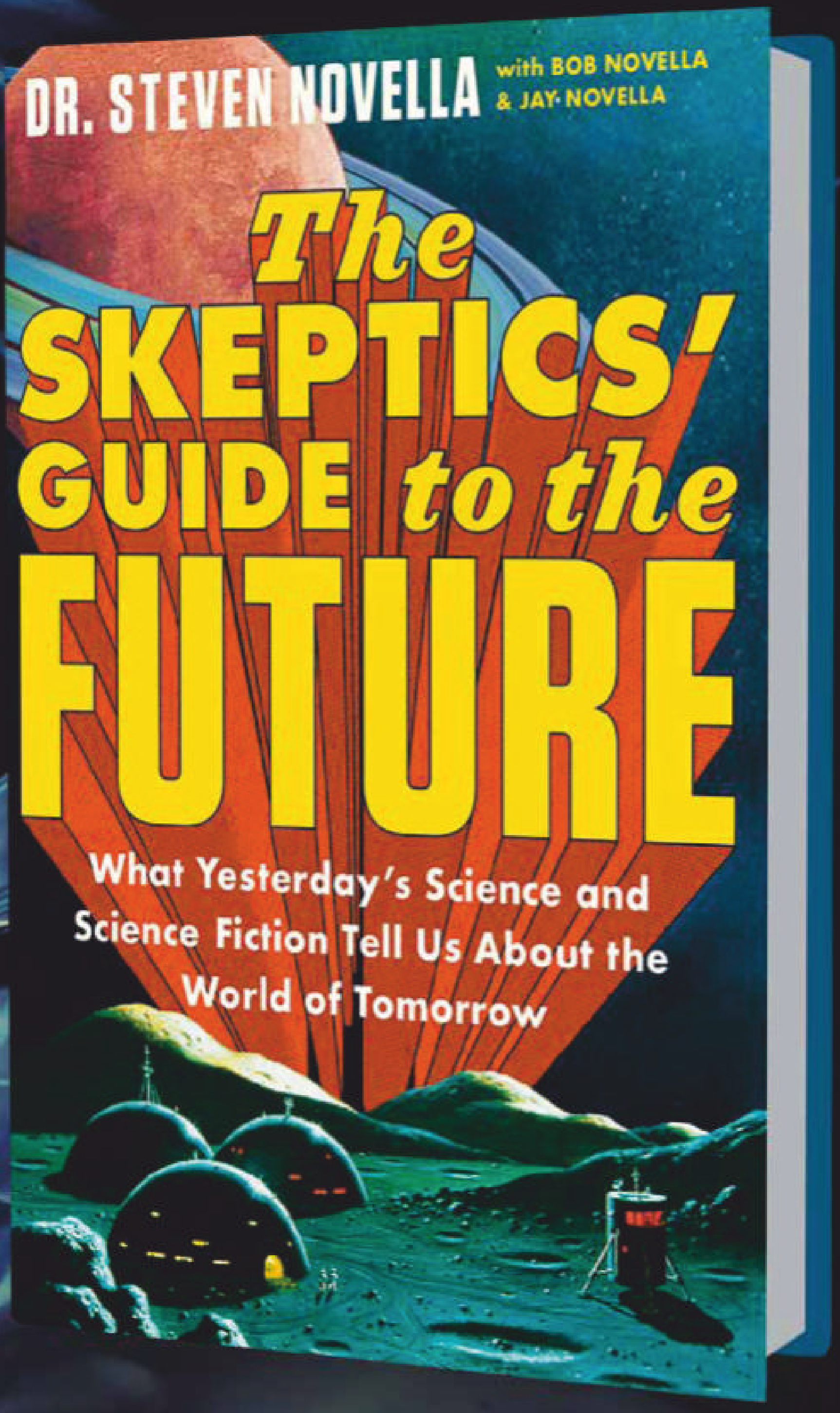
THE FUTURE IS nothing like we predicted... If we're honest with ourselves, science fiction has given us a lot of baggage. Just consider for a moment Arthur C Clarke's brilliant novel (and the movie adaptation), *2001: A Space Odyssey*. There we read about how, in the year 2001, humans would be heading to Jupiter. And yet, here we are, two decades on from then, and we're still not living in spaceships that look like cruise ships, flying around with jetpacks, and getting to know alien cyborgs which may or may not be trying to kill us.

While there have certainly been unbelievable technological innovations, many of the more outlandish ideas speculated by futurists remain nothing but fiction. And that is what *The Skeptics' Guide to the Future* is all about. It's a book where neurologist and Yale professor Dr Steven Novella (and his two brothers, Bob and Jay) cast a cynical eye on futurism.

Novella, known for his podcast 'The Skeptics' Guide to the Universe', looks at some of the books and movies we've enjoyed, pointing out the difference between science fiction, and, well, science. From Isaac Asimov to *Aliens*, *The Matrix*, *The Jetsons* and *Wall-E*, Novella explores what the future could be while debunking what will never be, because, when it comes down to it, the future is just that – futuristic. While ideas such as intergalactic travel and space elevators may sound pretty cool, Novella points out that predicting the future is often biased because our ideas are based on what we know. And, he says, we're actually pretty bad at predicting what will come next.

Novella's writing is well-researched and accessible. But it's also a lot to take in, especially when he goes into the nitty-gritty detail of science, emerging technologies, and how our choices today are what will shape the future. **PM**

> *'Predictions of the future are really just reflections of the present. And that means we're really bad at predicting what the future will bring.'*
> **– Steven Novella**


DR. STEVEN NOVELLA
with BOB NOVELLA & JAY NOVELLA
The SKEPTICS' GUIDE to the FUTURE
What Yesterday's Science and Science Fiction Tell Us About the World of Tomorrow

The Skeptics' Guide to the Future: What Yesterday's Science and Science Fiction Tell Us About the World of Tomorrow by Dr Steven Novella (Hachette Book Group), is out now, in good bookshops, and online.

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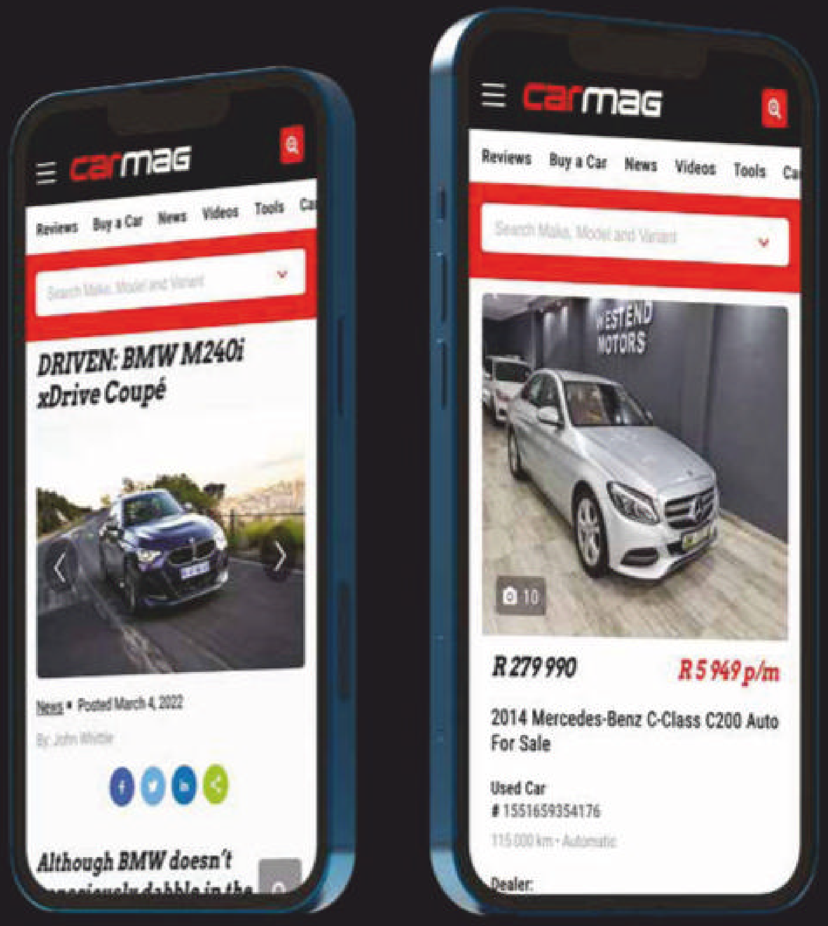
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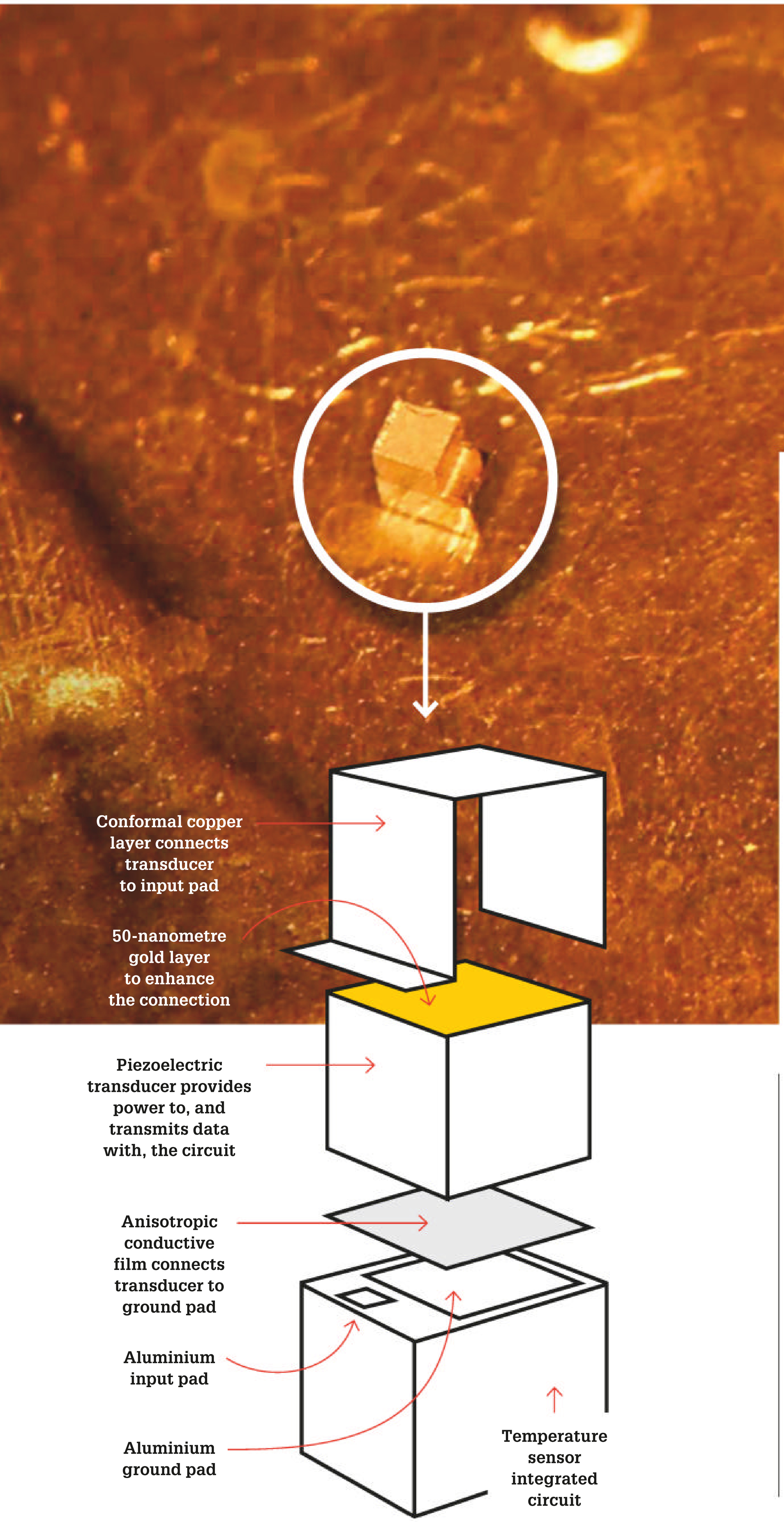
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Aluminium ground pad
Temperature sensor integrated circuit

The world's smallest implantable chip might save your life one day

SCIENTISTS AT COLUMBIA UNIVERSITY have created the world's smallest microchip, which can be implanted into the body and may eventually be able to detect medical conditions such as strokes. The chips, called motes, are the size of dust mites, measuring less than 0.1 cubic millimetre, and can only be seen under a microscope.

Motes operate as a single-chip system, complete with their own electronic circuit. They're implanted via hypodermic needle, and the data they collect is read using an ultrasound machine. And though the chips have only been tested in lab rats, the Columbia team hopes that one day they can assist in monitoring everything from glucose levels to oxygen saturation.

'These devices can be designed to sense things and communicate this information back to the ultrasound image, which also provides biogeographical data on where this particular information was sensed,' says lead researcher Ken Shepard, PhD, professor of electrical engineering and biomedical engineering at Columbia.

The motes' data transmission and power are both wireless. The interface that connects the human to the technology is integrated on the chip itself. And the device is small enough to be unobtrusive and amenable to the human body.

To power the chips, the scientists apply ultrasonic waves. (The motes run only when activated by an ultrasound machine.) Ultrasonic wavelengths are much smaller than the radio wavelengths used for most wireless communication, allowing the chip's extremely small size.

The chips are built with the same complementary metal-oxide-semiconductor (CMOS) process used in chips for computers, cars, and smartphones. CMOS chips are made with a pair of semiconductors attached to a secondary voltage source so that they work at opposite times; when one transistor is switched on, the other is switched off.

To have the chips communicate with ultrasound technology, researchers added a microscale piezoelectric transducer. It converts mechanical sound waves from the ultrasound machine into electrical signals and vice versa. It's covered with a small layer of gold on both sides to enhance connectivity. The motes also feature a layer of special conductive film and a thin sheet of copper.

'These are added after we get the chips back from the commercial foundry,' Shepard says. 'In addition, we have to etch and thin the chips to these very small form factors and coat them with a kind of plastic for biocompatibility.'

THE MOTES ARE THE SIZE OF DUST MITES, MEASURING LESS THAN ONE-TENTH OF A CUBIC MILLIMETRE.

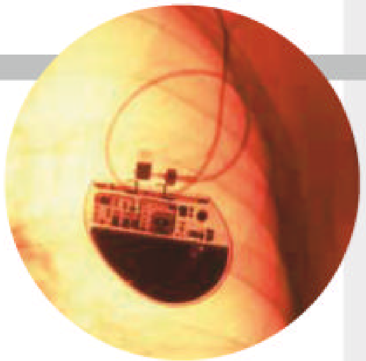
So far, the Columbia University team has successfully demonstrated the use of motes to monitor body temperature in rats – injecting the chips into the rodents' brains and hind legs to evaluate the chips' temperature-sensing performance – but human use will require considerable testing and FDA regulation.

Shepard and his team believe the motes will eventually prove useful in monitoring data other than temperature, from respiratory conditions to blood pressure. He says this could streamline the way we diagnose and treat diseases. In the future, implantable tech might be how your vitals are taken before a surgery or how tumours are located in a specific organ, or they might even be used in therapeutic settings to help treat chronic illnesses. **PM**

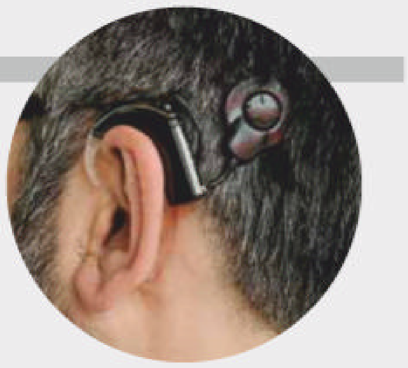
PHOTOGRAPHY: COURTESY CHEN SHI/COLUMBIA ENGINEERING (LEFT PAGE); RIGHT PAGE, FROM LEFT: GIPHOTOSTOCK/GETTY IMAGES, CHARLES O'REAR/GETTY IMAGES, WESTEND61/GETTY IMAGES

A BRIEF HISTORY OF REVOLUTIONARY MEDICAL IMPLANTS

1949 / The intraocular lens replaces a natural lens in a human eye. These artificial lenses help patients suffering from cataracts by similarly refracting light that enters the eye to help implant recipients focus and see again.



1960 / The first clinically successful pacemaker is implanted. This pacemaker used a mercury battery that powered transistors and a transformer on a circuit that was all set within epoxy resin and attached to electrodes that were placed within heart muscle tissue.



1977 / The modern cochlear implant is implanted to give patients with hearing loss a new sense of sound. This neuroprosthesis replaces the acoustic hearing process with electric signals that stimulate the auditory nerve.

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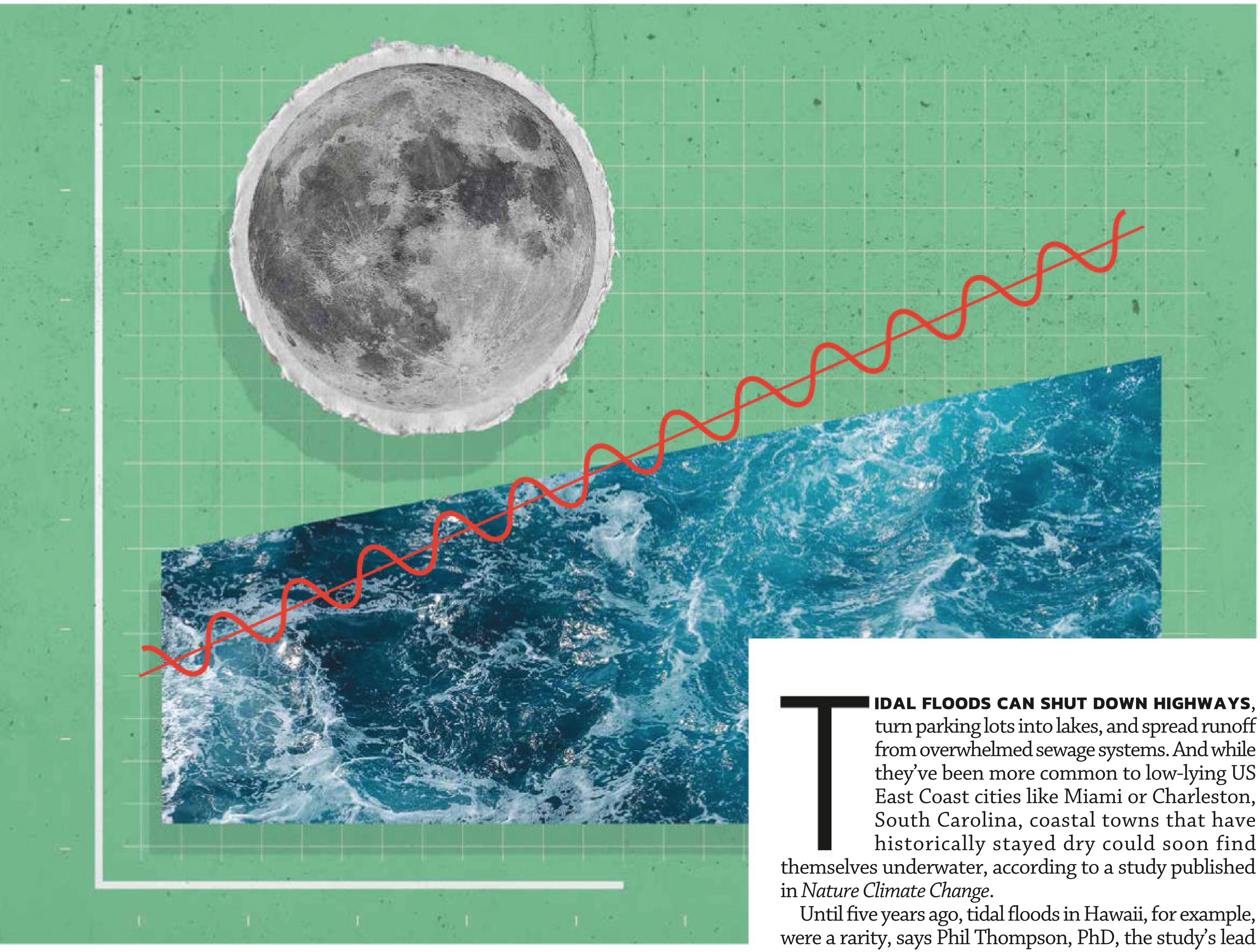

Tidal floods are coming to more cities, thanks to the Moon's wobble

TIDAL FLOODS CAN SHUT DOWN HIGHWAYS, turn parking lots into lakes, and spread runoff from overwhelmed sewage systems. And while they've been more common to low-lying US East Coast cities like Miami or Charleston, South Carolina, coastal towns that have historically stayed dry could soon find themselves underwater, according to a study published in *Nature Climate Change*.

Until five years ago, tidal floods in Hawaii, for example, were a rarity, says Phil Thompson, PhD, the study's lead author and a physical oceanographer at the University of Hawaii. If sea levels rise in line with the National Oceanic and Atmospheric Administration's (NOAA) Intermediate Sea Level Rise scenario (roughly one metre globally by the end of the century), Thompson and his fellow researchers predict a dramatic increase in tidal flooding events in some cities in the coming decades.

The planet has warmed more than 0.5°C over the past century. This warming has spurred polar ice sheets to melt and has driven the expansion of seawater, adding about 3 mm of water to the world's oceans annually. By the end of this decade, sea level is projected to have risen 90 mm to 178 mm compared with the year 2000.

While rising sea levels play the lead role in increased tidal floods, the Moon's oscillating orbit – a tide-altering phenomenon scientists have studied since 1728 – also contributes to the rise in floods. With everyday tides, the Moon pulls on Earth, causing the water to bulge. This protuberance – which can stretch to as much as 17 m – marches around the planet as it rotates, causing a rise-fall pattern in water levels. But the Moon's orbit also wobbles by a total range of about 10° while circling Earth. Picture a spinning coin on a tabletop: right before the coin falls to the table, it takes on a wobbly movement, spinning but also undulating up and down. This movement follows an 18.6-year pattern. For half of the cycle, the wobble shrinks the difference between high and low tide. The other half of the cycle amplifies tides, meaning high tides are higher and low tides are lower. In the early 2030s, the Moon's tidal suppression cycle will head into amplification.

While it was obvious tidal flooding has become more common around the country, says Thompson, it was unclear how bad flooding might be in the next few decades. To answer that, the team collected data from 89 coastal tide gauges across the US and studied all the possible changes that could occur over time: tides, nodal moon cycles, sea level rise, and natural fluctuations such as El Niño events. The researchers predict a rapid increase in tidal flooding around the mid-2030s. But it's the rate of change in some locations that was eye-opening for the team, says Thompson.

For instance, La Jolla, California, near San Diego, will remain steady at about 20 flooding events per year for the next decade, but from 2033 to 2043 'you get this really rapid change,' says Thompson. The flooding days almost triple as sea levels and tide amplification from the Moon cross a tipping point where flooding transitions from occasional to commonplace. The team also generated models for Honolulu, Boston, and St Petersburg, Florida, which saw similar dramatic increases.

These floods also tend to occur in clusters. Thompson compared tidal flood forecasts to hurricane season predictions. However, tidal floods are dependent on a number of conditions, such as weather, elevation, and local sea levels, and research revealed that different locations around the US will experience these clusters at different times.

> ▶ *FLOODING DAYS ALMOST TRIPLE AS SEA LEVELS AND TIDE AMPLIFICATION FROM THE MOON CROSS A TIPPING POINT.*

Thompson calls tidal flooding a threshold-based problem: You don't see it until it creeps into view and affects your daily life. 'The real impact of this wobble is not catastrophic flooding – we're talking about inches,' he says.

Runoff from overwhelmed roads and storm drains can create troublesome puddles, says Miyuki Hino, PhD, an environmental social scientist at University of North Carolina, Chapel Hill, who was not involved in this study. Floodwaters can pick up waste from failed septic tanks, along with oil and carcinogenic heavy metals that linger on the streets. 'There are definitely health reasons why you would want to avoid any amount of water,' she says. Wading through polluted waters can lead to skin rashes, infections, and gastrointestinal issues. Rising tide waters can also seep into privately owned wells, contaminating fresh sources of drinking water and leading to future health problems.

Coastal communities have about a decade to update their roads, sewage systems, and sea walls before tidal flooding increases exponentially, according to this research. 'We can't wait until it starts happening to do it,' says Thompson. 'We have to start now.' **PM**

PROTECT YOUR HOME FROM AN EXTRA-HIGH TIDE

▶ KNOW YOUR RISK

The first step in fortifying your home from flooding is to understand your risk. Do you live in a flood plain? Has your neighbourhood flooded in the past? Sites like First Street Foundation's FloodFactor can help you figure that out.

▶ PUT IN A SUMP PUMP

Installing a sump pump in low-lying areas – like your basement/cellar – diverts excess water into a well or specialised drainage system to prevent an unwanted indoor pool.

▶ GET YOUR HVAC OFF THE GROUND

Lifting your entire house is a tall order, but raising your electrical, plumbing, and HVAC systems can save thousands in costly repairs down the line.

PHOTO ILLUSTRATION: CREATED BY COLIN MCSHERRY USING GETTY IMAGES (MOON, SEA, TEXTURES) AND CAROLINE DELBERT (RED LINE)

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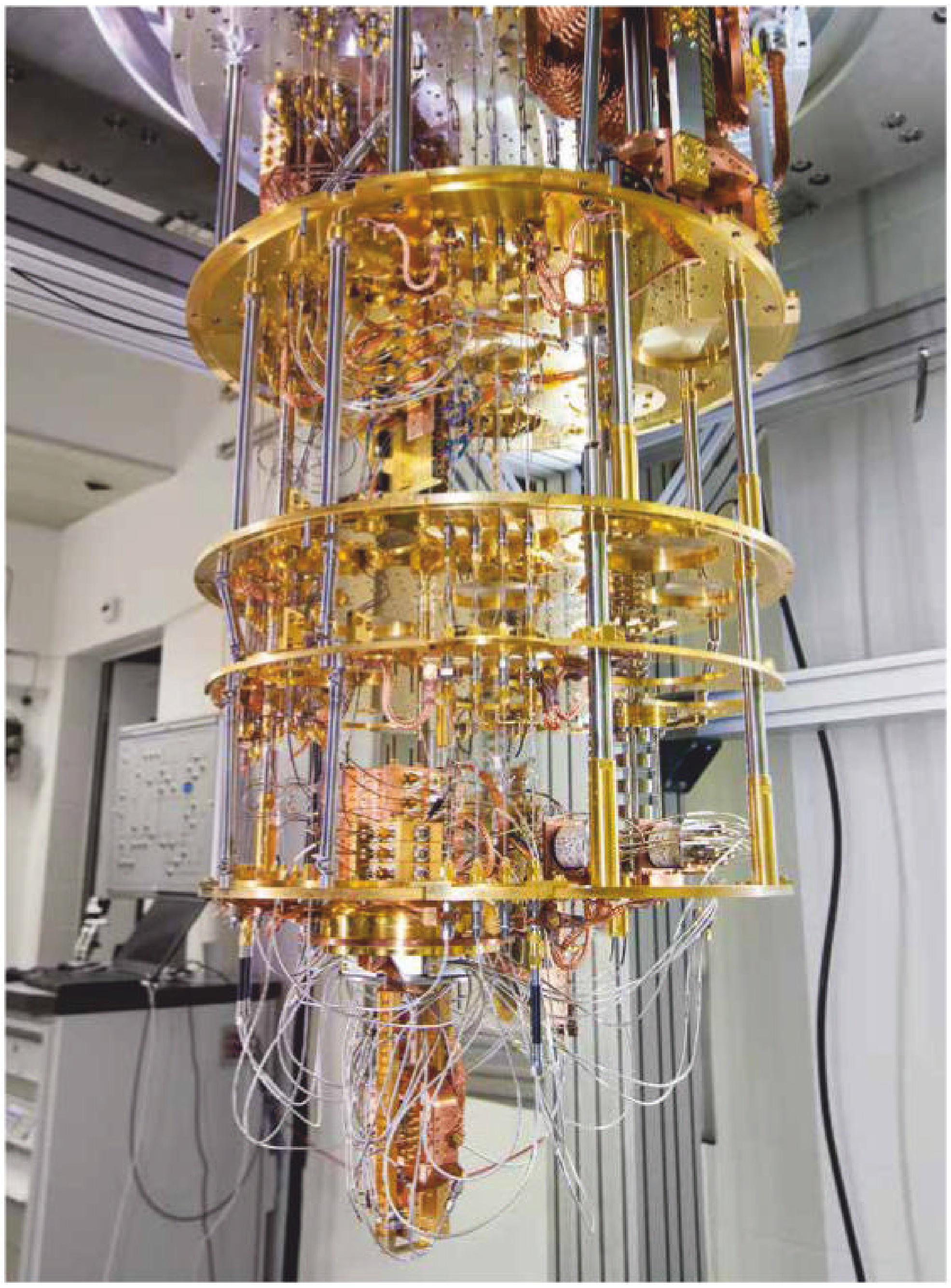
/ BY ADRIENNE BERNHARD /

Quantum cyberattacks are coming. This maths can stop them



IBM says that a quantum system with just 50 qubits might overpower today's top supercomputers.

ENCRYPTION – THE PROCESS OF SENDING A scrambled message that only the intended recipient's device can decode – allows private and public sectors alike to safeguard information. Traditional encryption uses schemes based on complex mathematics such as factoring (breaking an integer down to its prime factors) or discrete logarithm. Classical computers would require billions of years to crack these codes. Quantum computers, however, won't be stumped by such hard problems; their exponential leaps in processing power will render classical cyphers obsolete, potentially exposing troves of sensitive data across commercial entities, healthcare providers, government institutions and billions of individual users.

Experts are working to devise cryptographic schemes that can run on today's computers, but that can also be used in ciphers to protect data against quantum attackers.

Quantum computers can perform certain functions that ordinary computers simply can't; in part, this is because qubits (the way information is encoded on quantum computers) adopt the properties of quantum mechanics, using individual atoms, ions, photons, or electrons to take on a combination of various states at once. This gives quantum computers – once little more than a laboratory curiosity – access to a larger space of values than conventional computers, with their binary zeros and ones. Someday, quantum computers will be able to perform a vast number of calculations almost instantaneously, breaking the ciphers that protect personal data.

'We need to identify alternative problems we can use as the foundation for quantum-secure cryptosystems,' says Chris Peikert, professor of computer science and engineering at the University of Michigan. 'What hard problem are we going to use? How do we use that problem to encrypt messages securely?'

Enter lattices. Abstract algebraic structures, lattices are enormous grids with many individual points across two, three, or potentially hundreds of dimensions. In a high enough dimension, for instance, a bounded distance decoding problem – a type of lattice-based conundrum – should be able to flummox these machines (*see sidebar on next page*). 'The best algorithms we come up with still fail miserably,' says Peikert.

Lattices are infinitely large objects, but traditional computers only have a finite amount of memory to work with. So mathematicians need a succinct way to represent lattices if they're to use them in cryptography: what's called a lattice basis.

A lattice basis is a finite collection of points that can be used to reproduce any point in the grid that forms the lattice. In two dimensions, any given point has two co-ordinates – an *x* and a *y* value. Lattices used to create ciphers, however, are orders of magnitude higher in dimension. Points in these lattices might have 10 000 co-ordinates, rather than two. In small dimensions, lattice problems are easy for even ordinary computers to solve. But as the dimensions grow, these problems quickly appear to become intractable.

This curse of dimensionality confuses both traditional and quantum computers, particularly when they are trying to decode a location that's near – but not on – a lattice point.

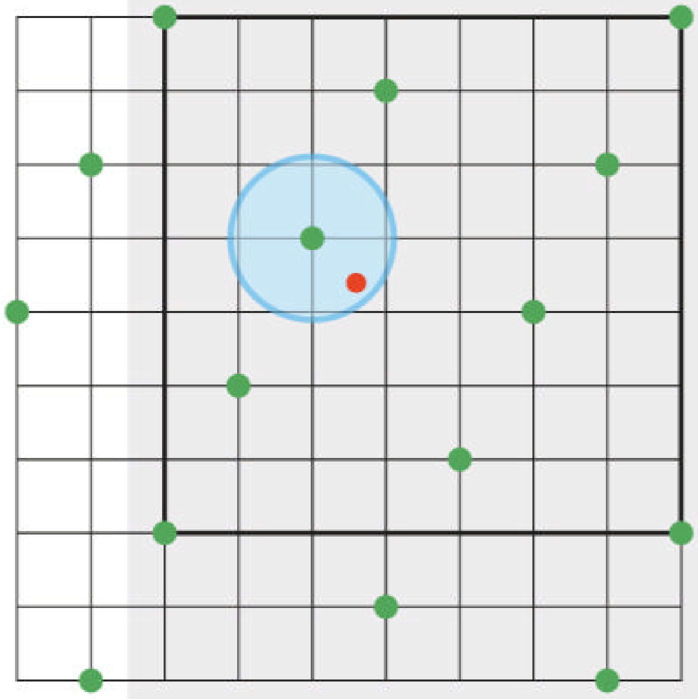
Let's say we plan to encrypt a single bit of data. Selecting a lattice point that corresponds to our data, we add a bit of random noise – that is, we slightly perturb the point, travelling a small distance so that we end up not on a lattice point, but close by, in the ambient space between lattice points; our target is no longer a lattice point. Where we've ended up becomes the ciphertext: the encrypted version of the data. In essence, bounded-distance decoding is the problem of recovering the original lattice point from this ciphertext.

Next, we send our ciphertext to the recipient, who will only be able to decrypt it on their device with a secret key – some special information about the original lattice. Without this key, experts believe that neither quantum nor classical computers will be able to decode the target point back to the original lattice point. The lattice is thus an ideal mechanism to devise encryption schemes for both traditional computers and quantum machines.

With quantum computing on the horizon, long-term security is paramount. Companies such as Google and Cloudflare have already started to deploy lattice-based cryptography within traditional internet protocols. Startups are banking on quantum technology to improve advances in finance, drug and materials discovery, data mining, and more. Unless cybersecurity can outpace the technology, however, quantum poses a risk for us all.

'Quantum computers will be able to retroactively break currently used codes, making them a threat not only to the future, but to the past and present as well,' says Peikert. 'The reality is sobering.'

BOUNDED DISTANCE DECODING, VISUALISED



'[This] figure depicts the bounded-distance decoding (BDD) problem on a two-dimensional lattice,' explains Chris Peikert (lattices used for encryption can have thousands of dimensions). The green points are some of the lattice points and the red point is the BDD 'target'. 'To solve the BDD problem,' Peikert says, 'the attacker must find the closest lattice point to any given target point.' In other words, decoding the lattice (being able to map all its points and crack the encryption, in this case) requires finding the bounded distance between the target point and the closest lattice point. Peikert adds: 'If we place equal-sized blue discs centred at every lattice point, then the target [point] must be inside one of them. The goal is to identify the lattice point at the centre of that disc.'

Lattice-based cryptography will permit us to replace our currently endangered encryption schemes; it will also allow for entirely new encryption methods for which we have no comparable analogues based on factoring or any other hard mathematical problem.

Just as a garden lattice is used to create privacy or to fence in an enclosure, mathematical lattices will help us shield our digital information. Startling in their efficiency, function and elegance, these abstract mathematical objects are the key to security in the post-quantum era. **PM**

PHOTOGRAPHY: COURTESY IBM

BUCKLE UP FOR A BONANZA YEAR OF MOTORSPORT AT KILLARNEY

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Killarney International Raceway, the home of motorsport in the Western Cape, is revving up for a memorable year of motorsport in 2023. National and international highlights include a round of the 2023 World Rallycross Championship, although the date has yet to be finalised.

Killarney also hosts the first and second-last rounds of the national championship Extreme Festival on Saturday 18 March and Saturday 9 September respectively, as well as the Cape Motorsport Festival on the second weekend of December, including the SA 9 Hour, the climax of the South African Endurance Racing Series, running deep into the night on Saturday 9 December.

Add to that nine rounds of the popular regional championship Power Series, sponsored for the 10th consecutive year by Wingfield Motors, eight rounds each of short circuit motorcycle racing, drag racing and local rallycross, in addition to eight rounds of Regional Karting and at least one national championship karting event on the one-kilometre "K" circuit, not to mention regular gymkhana and oval track racing events; motorsport fans are spoilt for choice at Killarney this year!

But wait, as they say, there's more: as part of our contribution to road safety we are hosting regular Robot Racing events on Wednesday evenings, as well as spinning on our brand new, purpose built 4500 square metre spinning pitch. We also host regular track days where local car and motorcycle enthusiasts (including you!) can learn from our experienced instructors how to enjoy their vehicles up to a standard rather than down to a speed limit.

Sunday sessions include cycle racing, duathlons and marathons; Killarney hosted a very successful duathlon in 2022 and was also the setting for the international 2021 Langa Marathon, where several Southern African athletes set qualifying times for the Beijing Olympics. The venue has now been measured and approved as an official World Athletics course for marathon events, and is widely regarded as the fastest marathon course in Africa, if not the world, thanks to its limited gradients and even surface.

And don't forget the biggest Motor Show in the Western Cape on the last Sunday in October! Charity events include the Truckerz Cansa Convoy and the 41st annual Cape Town Motorcycle Toy Run (last Sunday in November – save the date!)

Simply put, Killarney International Raceway provides affordable entertainment for you and the whole family. We have motor racing and other events practically every weekend – often more than one! – and with a huge variety of racing categories there really is something for everyone at the home of motorsport in the Western Cape.

You can also become a member of the Western Province Motor Club, which entitles you to free entry to all events hosted by the Club at Killarney as well as access to exclusive viewing areas such as the WPMC Members' Boma.

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/ BY THOMAS MUTCH /

Did the US lose a crucial testing ground when it left Afghanistan?

Members of the 82nd Airborne Division test C4 in Afghanistan in 2002.

FOURTEEN YEARS AFTER DUBBING ITS most powerful non-nuclear weapon ever developed 'the Mother of All Bombs' (MOAB), the US military finally found an opportunity to test the ordnance on the battlefield. In April 2017, intelligence officials had located a large cell of Islamic State Khorasan, the terrorist group also known as ISIS-K, hiding in a cave complex in Nangarhar province on the border with Pakistan.

The GBU-43/B Massive Ordnance Air Blast, to use its official name, had shown promise during demonstrations in testing grounds, such as Eglin Air Force Base in Florida, since its unveiling in 2003. But the Pentagon had never deployed it in actual battle, over concerns about civilian casualties. This cell, however, was believed to be remote enough for a Moab deployment.

According to the initial assessment by the Afghan Ministry of Defense and local media reports, the surprise blast swept through the caves with ease, causing at least 36 casualties, without harming any known civilians. (The US government never publicly released its own damage assessment.) For the Pentagon, this was more than a strike against terrorists: It served to demonstrate the feasibility of its newly developed weapons systems.

In many ways, Afghanistan was the ideal battleground for trialling new technology. Unlike in Iraq and Syria, much of the fighting took place in rural or mountainous areas with low concentrations of civilians. Using the GBU-43/B near urban centres would constitute a war crime under international law because the force would have been 'indiscriminate', causing civilian deaths and the destruction of critical infrastructure.

Using an active conflict to experiment and demonstrate the effects of new technology is nothing new. World War II saw the rapid development and deployment of technology ranging from computers for codebreaking to nuclear weapons. More recently, during the First Gulf War, the US and its allies tested satellite surveillance and target identification technology that enabled coalition forces to disable the once-fearsome Iraqi army.

In Afghanistan, the US military first demonstrated a major new capability before its invasion. A prototype Predator drone had been loitering over Kandahar in September 2000 when its operators spotted a tall, bearded man they recognised as Osama Bin Laden. But as *Stars and Stripes* reported, 'the elation was quickly erased by exasperation. The Predator had yet to be equipped with missiles.'

It was the start of a process that would lead drone warfare to becoming a major factor on the modern battlefield. In 2020 alone, the Trump administration used a Reaper drone to kill top Iranian general Qasem Soleimani, and Azerbaijan used Turkish- and Israeli-developed drones to overwhelm the Armenian military and end the decades-long Nagorno-Karabakh conflict in a matter of weeks.

The Afghan government, especially under former president Ashraf Ghani, was particularly pliant to US military requests, as it depended heavily on US support and aid. However, the American exit from Afghanistan may not affect the readiness of the military for future fights.

'While the conflict in Afghanistan allowed the testing and rapid development of communication and precision weapons capabilities, the Taliban didn't operate air capabilities,' says Justin Bronk, a research fellow for Airpower Technology at the Royal United Services Institute in Britain. In the case of an offensive conflict with a peer adversary such as Russia or China, these developments would be of limited use.

'The advantages of UAVs [Unmanned Aerial Vehicles], for example, are rendered useless in the context of an enemy that can cut the link between operator and aircraft,' Bronk says.

> " *THE ADVANTAGES OF UAVs ARE RENDERED USELESS IN THE CONTEXT OF AN ENEMY THAT CAN CUT THE LINK BETWEEN OPERATOR AND AIRCRAFT.*

And China, which has not been involved in a major military conflict since its war with Vietnam in the 1970s, is proving that a strong military may not even need an active testing ground. It recently shocked the Pentagon when it tested a hypersonic missile that circumnavigated the globe. And in their own Xinjiang province, the People's Liberation Army recently built two mock aircraft carriers that bear the distinctive traits of American carriers – to possibly practise locating, tracking, and destroying the US Navy's most precious asset in any future wartime. **PM**

TESTED IN AFGHANISTAN

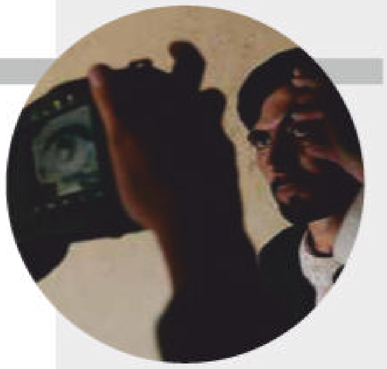
The nearly 20-year conflict saw the development of both transformational and controversial new military tech.

ON THE SPOT SURVEILLANCE

In 2019, the US equipped a battalion from the 82nd Airborne with experimental mini drones that could be carried on a soldier's person and flown with a handheld controller. This allowed them to rapidly scout nearby terrain from a safe position.

MEDICAL HELP ON THE BATTLEFIELD

As casualties from IEDs mounted, battle medicine developments focused on treatments that could be given at the scene. Medics developed tourniquets that could be applied with one hand, allowing injured soldiers to use it on themselves.



BIOMETRIC DATA COLLECTION

In one controversial development, US and local authorities trialled biometric data collection, such as iris scans, to compile large amounts of data on populations. Experts now worry the Taliban could use the tech to find Afghan allies who aided the US.

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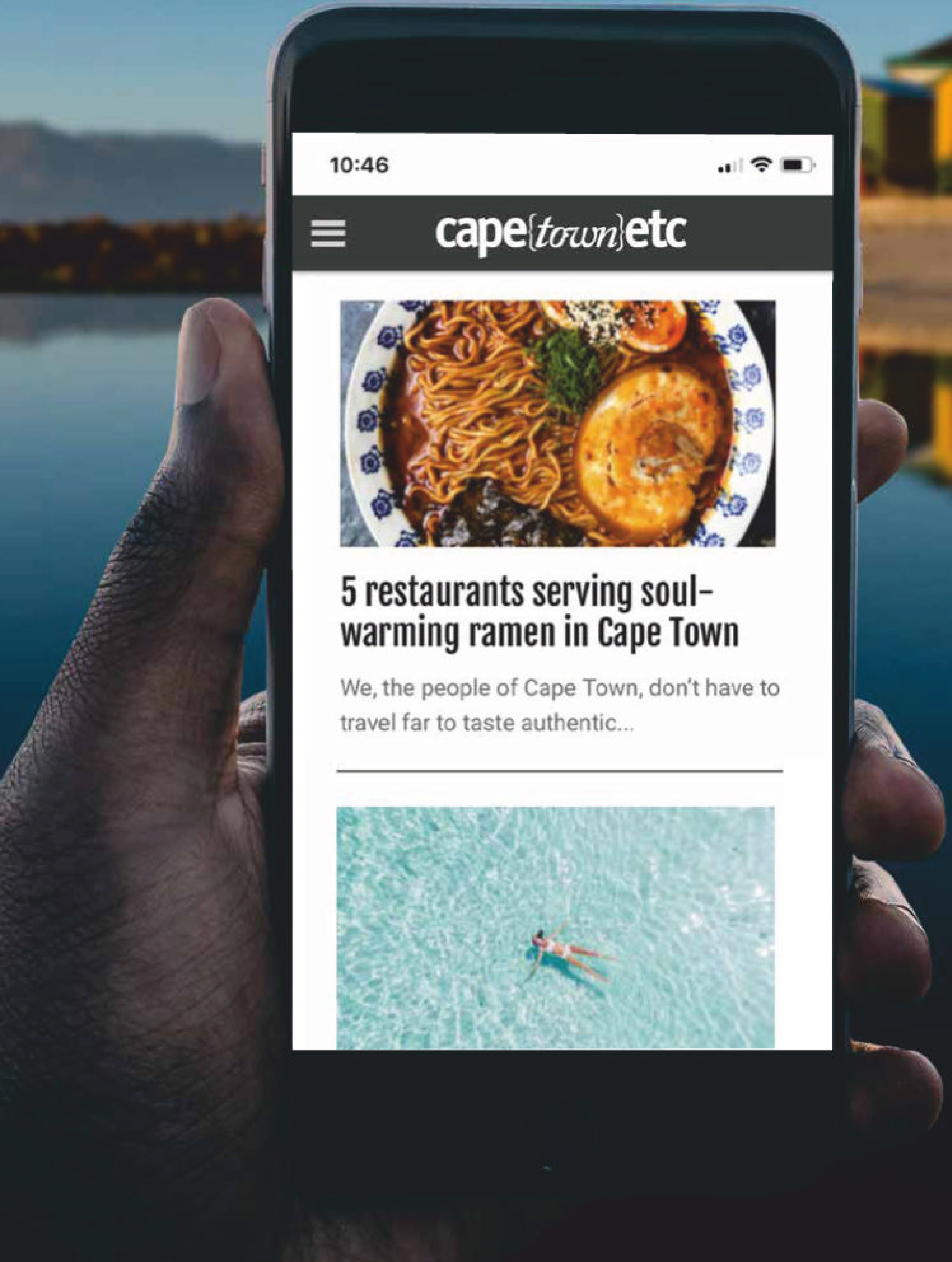

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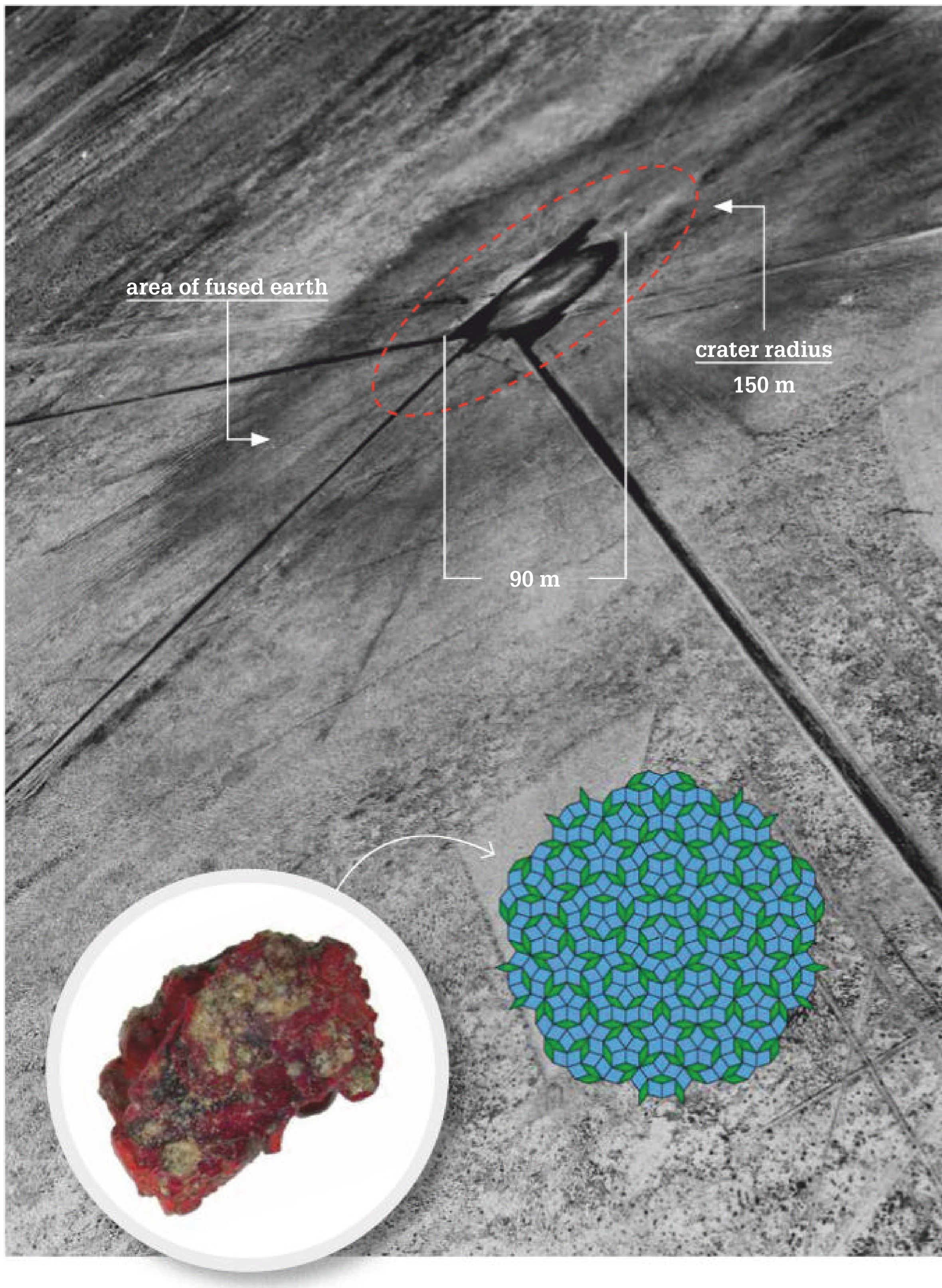
/ BY JENNIFER LEMAN /

The key to finding this 'impossible' material might be a nuclear explosion



The red variety of trinitite, seen above, is much rarer than the green or black varieties. The internal atomic composition of quasicrystals can be seen next to the red trinitite.

A DECADES-LONG QUEST TO FIND quasicrystals – a crystal-like material with a seemingly impossible structure – has led researchers to an unlikely location: the site of the Trinity test, the first atomic bomb blast. When the US military detonated a plutonium bomb over the New Mexico desert on 16 July 1945, sand fused with copper cables that stretched to the top of the bomb's detonation tower, forming a glassy mineral called red trinitite.

From a sample of this mineral, Luca Bindi, PhD, a mineralogist at the University of Florence in Italy, and his colleagues were able to isolate a previously undiscovered quasicrystal. The discovery, announced earlier this year in the *Proceedings of the National Academy of Sciences*, could shed light on how these unusual grains form. It's the oldest anthropogenic quasicrystal found yet.

Quasicrystal alloys could be used in LED lights, diesel engines, and even surgical instruments. Thanks to their characteristic hardness and slipperiness, they could act as a substitute for the Teflon coating on cookware, and could be added to steel alloys to strengthen body armour. And because of their low heat conductivity, some types of quasicrystals could be tapped to develop heat-insulating coatings. The physical properties of these mysterious microstructures depend on two things: the elements that make up the material, and the arrangement of those elements.

Atoms found in regular crystals – be they salt, quartz, or diamond – have a uniform and repeating lattice-like structure. Depending on their chemical composition, these atomic building blocks can take on two-, three-, four-, or six-fold rotational symmetry, meaning they can be rotated around a point in symmetrical fashion without leaving gaps. The atoms in quasicrystals, however, break the long-established laws of crystallography and have impossible symmetries, such as five-fold, which wouldn't naturally rotate symmetrically.

While the red trinitite sample's soccer ball–like icosahedral symmetry (20-faced, with every face being an equilateral triangle) has been seen before in other quasicrystals, its chemical composition – mainly iron, copper, calcium and silicon atoms – is entirely new to science. The inclusion of silicon, for instance, is particularly unusual as most known quasicrystals are primarily made from metals.

The race to understand how quasicrystals form has been dramatic. Daniel Shechtman, PhD, now a materials scientist at the Technion Israel Institute of Technology in Haifa, discovered the first quasicrystal in an aluminium-manganese alloy in 1982. The revelation was so controversial, he was asked to leave his lab. (He eventually earned the 2011 Nobel Prize in Chemistry for his work.) For a while, it seemed these structures could only be generated in a laboratory – often by melting different minerals into a homogenous soup, then re-solidifying them.

In 2007, Paul Steinhardt, PhD, a theoretical physicist at Princeton University in New Jersey, and his team plucked the first naturally occurring quasicrystal from a meteorite found in northeast Russia. At the time, they surmised it must have been created by a powerful impact, such as the collision of two celestial bodies. To test this theory, the team travelled to a specialised laboratory at Caltech and shot a projectile at a stack of minerals. The experiment generated a powerful pressure shock wave. 'We were able to reproduce, in fact, the same quasicrystal we had seen in the natural meteorite through this artificial process,' explains Steinhardt. He and his colleagues theorised there could be other scenarios powerful enough to create a quasicrystal.

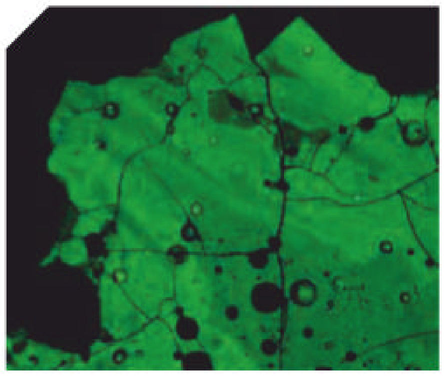
Enter the atomic bomb. 'The interior of a nuclear fireball is just a really strange place for the chemical bonding of materials,' says Chloe Bonamici, PhD, a geochemist at the University of Wisconsin, Madison, who was not affiliated with the research. 'The temperature, the pressure – all of those things are fluctuating on the scale of microseconds.' In other words, this high-pressure, high-temperature environment is a perfect quasicrystal nursery.

Bindi scoured the internet for samples of red trinitite, then sliced, polished, and analysed the chemical composition of the samples until he found the prized quasicrystal. He was able to wriggle the tiny structure – no wider than one-tenth the width of a human hair – loose with the point of a needle. Its discovery within the wreckage lends support to the theory that high-pressure shock waves can 'lead to new forms of matter that were not known before – in this case, new forms of quasicrystals,' Bindi says.

And now that researchers have the chemical formula of the red trinitite quasicrystal pinned down, they can try to recreate it in a lab and measure its physical properties.

The ultimate goal, Steinhardt says, is to tweak the chemical building blocks of lab-grown quasicrystals in order to optimise them for different industrial uses. Tracking down variations of these tiny structures can shed light on new, strange chemical combinations that scientists might not have thought to try.

Steinhardt and Bindi aren't limiting their search to nuclear explosions and meteorite impacts – they plan to search for these elusive structures in fulgurites, the material that sometimes forms from a lightning strike, and in lunar rock samples. The race to find more quasicrystals – and possibly apply them to future technologies – is heating up. **PM**



QUASICRYSTALS COULD AID NUCLEAR WEAPONS FORENSICS

There's a chance quasicrystals could be used in nuclear forensic chemistry, explains Chloe Bonamici, PhD, a geochemist at the University of Wisconsin, Madison. The chemical makeup of the quasicrystal – composed of nearby elements – could help identify a bomb's components, or reveal the location of previous, covert detonations. Publicising this information could help deter bad actors from using nuclear weapons. 'If we can read the record that is in the solid pieces of nuclear debris, then we can make sure that other groups know, "We can find you and we can make you accountable if you should happen to use one of these weapons,"' Bonamici says. And unlike a fingerprint or a sample of DNA, these crime-scene clues won't degrade.

PHOTOGRAPHY: GETTY IMAGES (EARTH), ELENI DIMOU (GRAPHICS), LUCA BINDI AND PAUL J STEINHARDT (CRYSTAL), INDUCTIVELOAD/WIKIMEDIA COMMONS (PATTERN), LUCA BINDI AND PAUL J. STEINHARDT (X-RAY)

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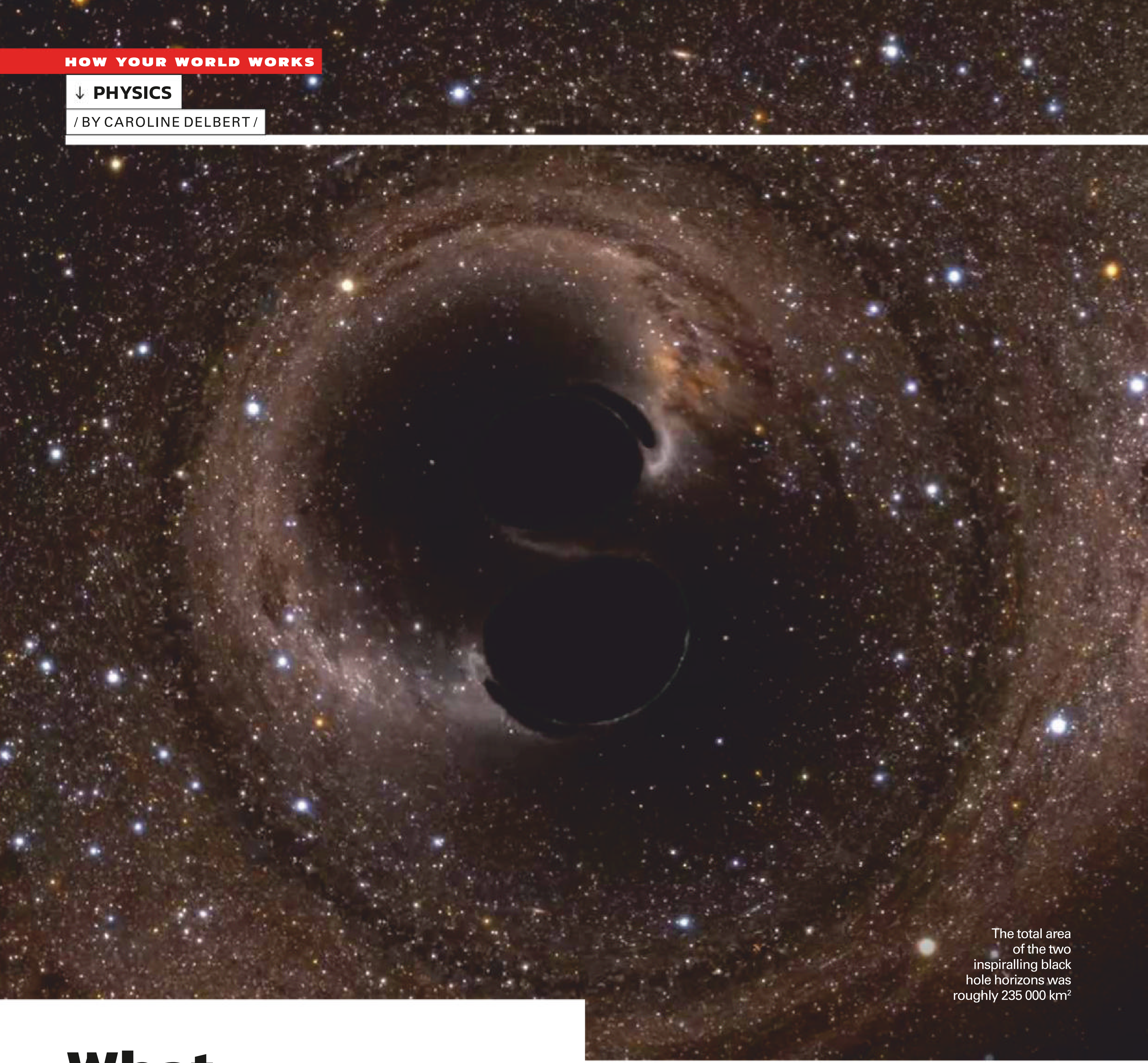
↓ PHYSICS

/ BY CAROLINE DELBERT /



The total area of the two inspiralling black hole horizons was roughly 235 000 km²

What happens when two black holes collide?

FOR THE FIRST TIME, WE'VE OBSERVED A 50-YEAR-OLD theorem from Stephen Hawking in the natural world. Scientists from the Massachusetts Institute of Technology (MIT), California Institute of Technology, Cornell University, and Stony Brook University analysed the gravitational wave data of two inspiralling black holes. What they found in the collision proved Hawking's Area Theorem: The area of a black hole's event horizon cannot shrink.

When a binary black hole system inspirals, the orbits of the two black holes shrink, and the system begins emitting gravitational waves. The emission rate increases as the orbits shrink further and gain speed, and when a merger finally occurs, wave emission peaks. The two black holes become a single, new black hole, and according to Hawking's theorem, that new black hole should be equal in area to the total area of the original two black holes. That's exactly what the researchers found per the wave data of the observed inspiralling system.

The confirmation brings us closer to understanding the intricacies of black hole functions, says Riccardo Penco, PhD, assistant Professor of High Energy Physics Theory at Carnegie Mellon University. 'The detection of gravitational waves allows us to test black holes directly (as opposed to just inferring their existence indirectly by studying the motion of other objects around them). For the longest time, we have studied black holes as mathematical objects endowed with a remarkable set of properties (Hawking's area law being one of them). We are now in a position to test these properties experimentally.'

Per Hawking's calculations, if a black hole changes in area, its event horizon would stretch or constrict in correspondence with its new size. The event horizon, the area of effect for a black hole's gravitational field, is the point of no return for anything – including light – orbiting the black hole. An object would need to travel faster than the speed of light in order to escape.

Penco says Hawking's Theorem holds true for the black holes observed by the Laser Interferometer Gravitational-Wave Observatory (LIGO) – a pair of US facilities built to study gravitational waves – whose work these researchers used for their findings. But Hawking's Theorem could apply to other black holes as well, those that at first seem to defy the theorem until they prove applicable to another concept hypothesised by the physicist.

'Hawking showed that when quantum mechanical effects [like the behaviour of subatomic matter and light] are taken into account, a black hole can spontaneously reduce its surface area over time by emitting radiation,' says Penco. Black hole evaporation, also called Hawking radiation (*see sidebar*), is theorised electromagnetic radiation spontaneously expelled by black holes. So Hawking's Area Theorem has an exception, Hawking radiation, touted by Hawking himself.

LIGO detected the first gravitational wave signal in this study – essentially a ripple in space-time resulting from cosmic interactions – in 2015. The signal, they discovered, was the product of two merging black holes (which typically cause the stronger gravitational waves), along with a vast amount of energy that rippled across the space-time continuum.

The researchers posited that if Hawking's Area Theorem held up, the event horizon area of the new black hole created from the merger would not be smaller than the total event horizon area of its parent black holes. To test their hypothesis, they split up the gravitational wave data from the system into two sections – before the merger and after the merger – then analysed both sections to see how their event horizon areas compared. The scientists then re-analysed the wave data and found that the two areas are statistically the same – the total event horizon area did not decrease post-collision – within a 95 per cent confidence margin.

It would seem from the analysis, then, that the laws of 'regular' physics, such as the law of conservation of mass, can still be applied to the study of black holes, where physics can become more theoretical in situations unfamiliar to the Earth-bound human experience. Working in reverse, observing real-life data to interrogate the laws that might govern black hole behaviour, could be a practical way to advance the entire field of cosmology. With this black hole mergence, other scientists now have a concrete example to reference as they continue to study space.

Still, Penco says this 'doesn't fundamentally alter our understanding of black holes [just] because it confirms our theoretical expectations.' Confirming a theory helps us better understand the mechanics of mysterious cosmic phenomena such as black holes but it also creates a more important tie between the tactile scientific experience on Earth and the theoretical science of space. 'It's always important to be able to confirm experimentally,' Penco says. 'It's another step forward towards a deeper understanding of black holes.' **PM**

The low-down on Hawking radiation

Proposed in 1974, Hawking radiation might cause a black hole to shrink. Subatomic particle pairs near the event horizon might split, with one particle – a photon or neutrino, perhaps – escaping and another, of negative energy, disappearing into the black hole. This influx of negative energy could eventually reduce the black hole's mass until it disappears. This means a black hole's size is inversely proportional to its temperature – the smaller the black hole, the warmer it is. – *Daisy Hernandez*

PHOTOGRAPHY: SIMULATING EXTREME SPACETIMES (SXS) PROJECT/COURTESY OF LIGO

↓ MACHINES

/ BY CAROLINE DELBERT /

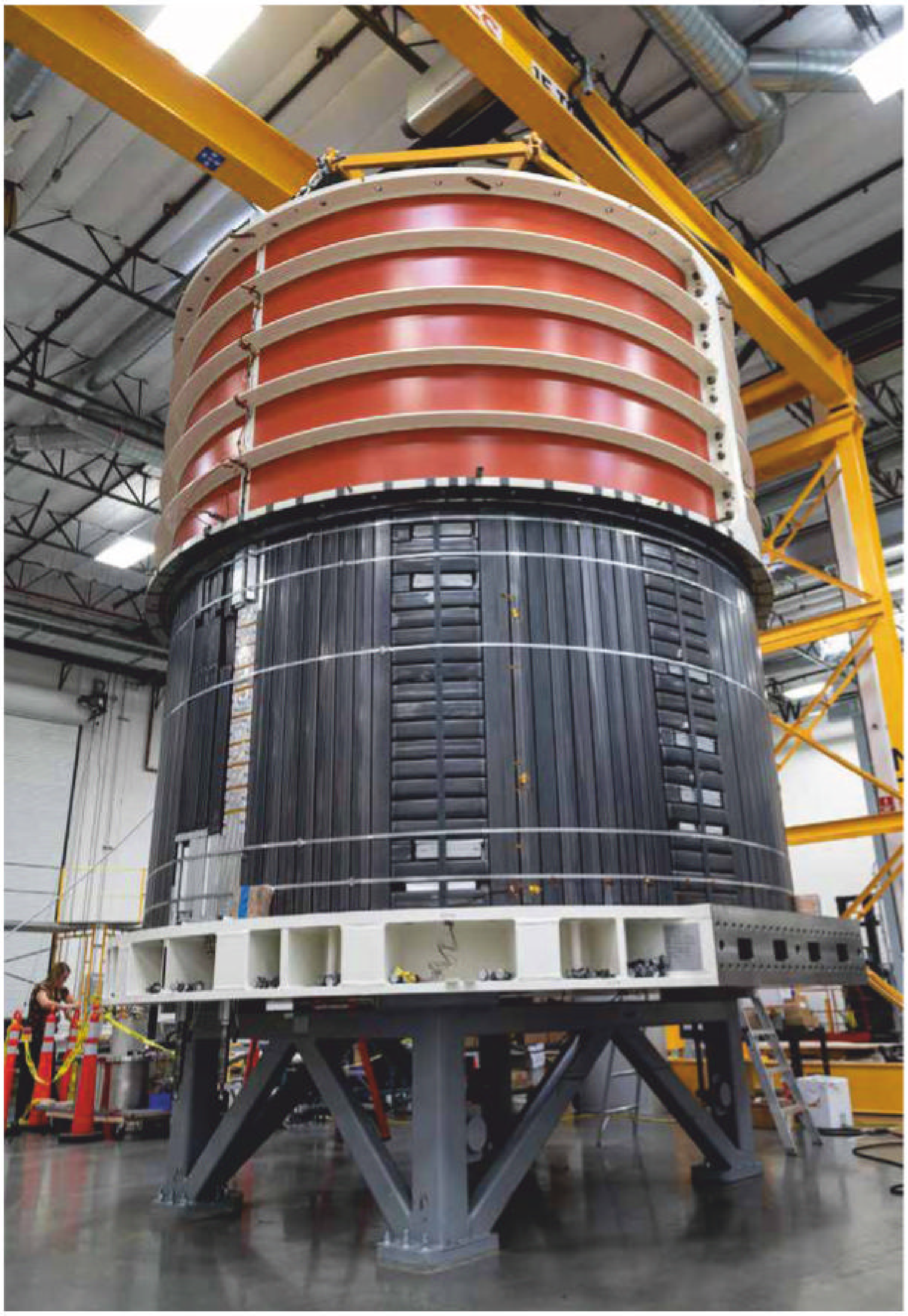
How do you build the world's largest magnet? It's complicated

THE WORLD'S LARGEST AND MOST POWERFUL magnet, the 'Central Solenoid', is finally here – or at least, the first piece of it is. Fully assembled, it will be 18 m tall, 4 m wide, and weigh about 910 metric tons, meaning the decade-in-the-making magnet will be truly massive. Appropriately, it will find a home in southern France at the world's largest fusion reactor, the International Thermonuclear Experimental Reactor (ITER), this year.

Constructing a magnet of this magnitude is one huge job. Engineers and technicians at General Atomics in San Diego have spent more than half a decade designing, fabricating, and testing the various components of the Central Solenoid in its production facility – and that's only half the battle. Transporting each piece of the magnet is a Herculean endeavour in and of itself, requiring custom-built roads and cranes to haul them.

It makes sense when you consider the scope of the magnet. 'If you think about an aircraft carrier, which weighs … about 100 million kg, the Central Solenoid will generate enough magnetic force that it would be able to lift it 1.8 m into the air,' says John Smith, director of engineering and projects for General Atomics.

In August 2021, the magnet's first module arrived in France, but the Central Solenoid will eventually consist of six pieces in total. Each module is 2.1 m tall, 4.2 m wide, and 114 000 kg. Once complete, engineers will stack and link the modules together at the centre of the reactor.



This machine's magnetic force will reach a strength 280 000 times stronger than Earth's magnetic field.

The superconducting electromagnet is the 'beating heart' of the ITER tokamak – a magnetic confinement device that produces controlled thermonuclear fusion power. If you think of ITER as a massive electrical transformer, the Central Solenoid is the 'primary', meaning it will guide 15 million amps of electrical current into the doughnut-shaped tokamak body, helping to shape and stabilise the sun-hot plasma inside.

While the giant ITER reactor is more of a prototype for future large-scale tokamaks, and will not generate electricity, it will be a means of proving that fusion is a feasible, carbon-free energy solution. So far, no existing fusion reactor has even come close to producing more energy than it uses. This is a huge sticking point, because the reactors use an enormous amount of electricity. But armed with the Central Solenoid as its powerhouse, ITER just may become the blueprint for sustainable energy.

So how do you actually build a magnet of this calibre? It's fundamentally the same process you'd use to create any coil-wound electromagnet in your garage: simply twist conductive wire around a sturdy core. Of course, this magnet is almost unfathomably huge and is made of superconducting niobium and tin, making matters a bit more complicated.

First, General Atomics sources the cables from a manufacturing plant in Japan. Then, the materials are carefully wound together and subjected to five weeks' worth of heat treatment, topping out at 650°C. By 'cooking' niobium and tin into the chemical compound Nb_3Sn, the scientists transform the simple conductor into a superconductor. Temperatures are increased very progressively, maintained, and then decreased gradually again. Finally, the company gently loosens the springy coils so that a special machine can wrap all 5.6 km of cable in insulation, inch by inch.

Afterwards, engineers use 290 km of tape to cover all of the superconducting cable. Meanwhile, the air inside the magnet module is replaced with about 3 800 litres of resin, cured at 125°C until solid. This saturates and sets the insulation material, preventing unwanted bubbles. Then, the entire unit must be supercooled to just 4 Kelvin (about –270°C) for testing.

So far, the first module passed with flying colours. General Atomics will manufacture the other five modules on a staggered basis, rotating among the different construction stations for steps like heat-treating the coils, and then taping them. 'It takes two years to make a coil from start to finish,' Smith says.

The difficulties don't end with the manufacturing process, though. General Atomics is based in California, but each module needs to make it all the way to Saint-Paul-lez-Durance, France, making the transport process a bit tricky (*see sidebar*). After loading each module into specialised heavy transport vehicles, General Atomics will ship the pieces to Houston, where a transport ship will then pick them up. The company sent Module 1 to sea in late July 2021, and it arrived in France by mid-August.

Luckily, this isn't ITER's first rodeo – the team is used to finagling huge pieces of equipment. For instance, engineers constructed a specially prepared, heavy-duty road to the facility in the south of France, allowing workers to bring immensely heavy items overland – not dissimilar to the special roads that move space vehicles from preparation spaces to the launchpad. **PM**

> *THE SUPERCONDUCTING ELECTROMAGNET IS THE 'BEATING HEART' OF THE ITER TOKAMAK – A MAGNETIC CONFINEMENT DEVICE THAT PRODUCES CONTROLLED THERMONUCLEAR FUSION POWER.*

Moving the massive magnet

Transporting even one of the magnet's modules requires ingenuity at every turn. The main mechanism is an enormous crane – but that's complicated, too. 'You have to have a crane to build the crane,' Smith says. 'The body of the crane fits on one nine-axle truck. They have 40 to 60 semi-trucks of parts, components, deadweights, and counterweights that are required to come on site for this.'

That's all just to move the magnet on to the truck. 'I'm awed by the truck that takes this thing out of here,' Smith says. 'There's a petrol engine powering a hydraulic system, and there's a guy steering the back set of wheels. I was surprised how easily they can actually manoeuvre. They had one puller unit and two pusher units. There are two big semi-truck diesels behind it pushing it the whole time.'

From there, the module is loaded on to a train, where multiple engines help to pull the massive payload. It eventually reaches the Caribbean Sea, where it's loaded on to a ship designed to carry easy-to-load shipping containers. With the module secured using extreme care, it's ready for its journey to France.

PHOTOGRAPHY: COURTESY GENERAL ATOMICS

/ BY MATT CRISARA, AUTOS EDITOR, US EDITION /

F1 taught me that speed starts with comfort

GETTING COMFORTABLE / I position my seat as low as possible and the steering wheel up high and easy to reach.

AS A FAN OF MOTORSPORT, I'M ALWAYS fascinated with the finer details that go into Formula One racing. Piloting the fastest racing cars on the planet subjects drivers to savage forces – up to 6 G's under braking – which has led to an almost endless pursuit of comfort. Teams spend hundreds of hours and millions of dollars optimising cockpit ergonomics to ensure their drivers aren't distracted by aches and pains during a two-hour Grand Prix. To offer some perspective, it's not uncommon for 2007 F1 world champion Kimi Räikkönen to nap in between qualifying sessions while strapped into his car.

Being an impressionable petrolhead, I began tweaking the seating position in my Volkswagen GTI back in college. The improved ergonomics paid massive dividends even if I wasn't driving on a track. On weekends, I'd drive across the southwestern states for mountain bike races, and after hours behind the wheel, I'd emerge with fresh legs and ready to compete.

After countless hours in my GTI, I've continued to refine what works best for me. And I've found that any car enthusiast can reap rewards similar to F1 drivers by dialling in their ergonomics: improved reaction times, reduced fatigue, and increased ability to focus on the road ahead.

Let's start with seat height. Most car enthusiasts insist on driving in the lowest possible seat position to drop their centre of gravity, but that can obstruct outward visibility. I've found the best results by starting at the lowest setting and working my way up until I have a clear 360° line of sight around the car.

Next: your distance to the pedals. Sitting too close can lead you to accidentally press the pedals, while being too far will force you to reach for full extension – unnecessary work that leads to fatigue. Set your seat at a distance where your leg is just about to reach full extension at the end of the pedal travel.

The steering-wheel position is also a safety concern. Sitting too close increases your risk of an airbag injury in a crash – they can generate roughly 8 900 Newtons (almost 910 kg of force) while deploying. Thankfully most modern vehicles allow you to move the steering wheel forward and back as well as up and down. A good test of steering-wheel position is to place your palms on the top of the wheel: You want a slight bend in your elbow. I also make sure the steering column is high enough to clear my knees while I'm using the clutch.

Feeling out the ideal driving position will take some trial and error, but it's worth the time investment. I still mess with my position every so often to maximise comfort and engagement with my vehicle. If nothing else, it will give you a good reason to go for a drive. **PM**

MATT CRISARA IS THE AUTOS TEST EDITOR IN THE US.

PHOTOGRAPHY: TREVOR RAAB

81/1000 CHILDREN BORN IN AFRICA IN 2015 DIED BEFORE AGE 5

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1/3 OF DEATHS ARE IN THE NEONATAL PERIOD

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GIZZU 518 Wh Portable Power Station

This ruggedly designed big guy in the range provides backup power at home, but is also an ideal companion for camping trips, enabling you to operate small appliances with consumption requirements of less than 500 W. It can power a 42" LED TV (100 W) for 5 hours.
(Product code: GPS500)

• Li-ion technology • 140 000 mAh capacity • 1 000 charging cycles • 500 W output • 3-prong SA plug included • PD, USB, DC and AC output ports • LED flashlight • 5 140 g

RRP R8 999

GIZZU 296 Wh Portable Power Station

With slightly smaller dimensions and overall mass than the 518 Wh device, this power station still packs a punch, while being highly portable. It'll easily handle your fibre router, while recharging your laptop too, ensuring Eskom won't interrupt your work day. On camping trips it'll keep your mini fridge running, as well as other key devices.
(Product code: GPS300)

• Li-ion technology • 80 000 mAh capacity • 1 000 charging cycles • 300 W output • 3-prong SA plug included • PD, USB, DC and AC output ports • LED flashlight • 3 400 g

RRP R5 999

GIZZU 155 Wh Portable Power Station

Even more compact and portable, and weighing a little under 2 kg, this device can be stashed in a daypack for adventures in the great outdoors. But it's perfect, too, for powering your fibre router, a light or two, charging your computer, phone, and more. **(Product code: GPS150)**

RRP R2 999

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- 150 W output
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- PD, USB, DC and AC output ports
- LED flashlight
- 1 890 g

GIZZU 100 W 46 Wh Mini DC UPS

If keeping your fibre internet up and running is a high priority, this is the device to go for. It provides an uninterrupted power supply to your router and ONU (optical network unit), so you can keep on working, streaming content, or surfing the web when the power's down. It can also power CCTV cameras and VoIP phones. **(Product code: GUP100W)**

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• Li-ion technology • 14 400 mAh capacity • 100 W output • DC output: USB and POE ports • 900 g

GIZZU 60 W 65 Wh Mini DC UPS

Super simple to install, and boasting a slightly higher capacity than the 100 W UPS, this model will keep your router and ONU running for longer, without mains power. It can also provide power to CCTV cameras and VoIP phone systems, and juice up your phone, tablet and other compact devices. **(Product code: GUP60W)**

RRP R1 599

• Li-ion technology • 17 600 mAh capacity • 60 W output • DC output: USB and POE ports • 940 g

GIZZU 30 W 32 Wh Mini DC UPS

If keeping your fibre ONU and router powered up at all times is important, this compact UPS will do the trick, for around 10.6 and 3 hours respectively. It can also power a CCTV camera, and charge devices such as cell phones and tablets. **(Product code: GPS150)**

RRP R999

• Li-ion technology • 8 800 mAh capacity • 30 W output • DC output: USB and POE ports • 430 g

RRP R1 299

GIZZU 1000 A 10 400 mAh Jump Starter

Yes, this compact little fella will jump start your vehicle (petrol, up to 5 litre capacity; diesel, up to 3 litre capacity), meaning you'll never have to worry about a flat battery again. But it's also a flashlight, and, using the USB port, enables you to recharge your mobile devices. **(Product code: GJS10000)** PM

• Li-ion technology • 10 400 mAh capacity • 1 000 charging cycles • 2-in-1 USB cable • Sparkless smart cable • Start current: 500 A; peak current: 1 000 A • 361 g

To view the full range of GIZZU products, visit *syntech.co.za/brands/gizzu*. All of these devices are available at *takealot.com*.

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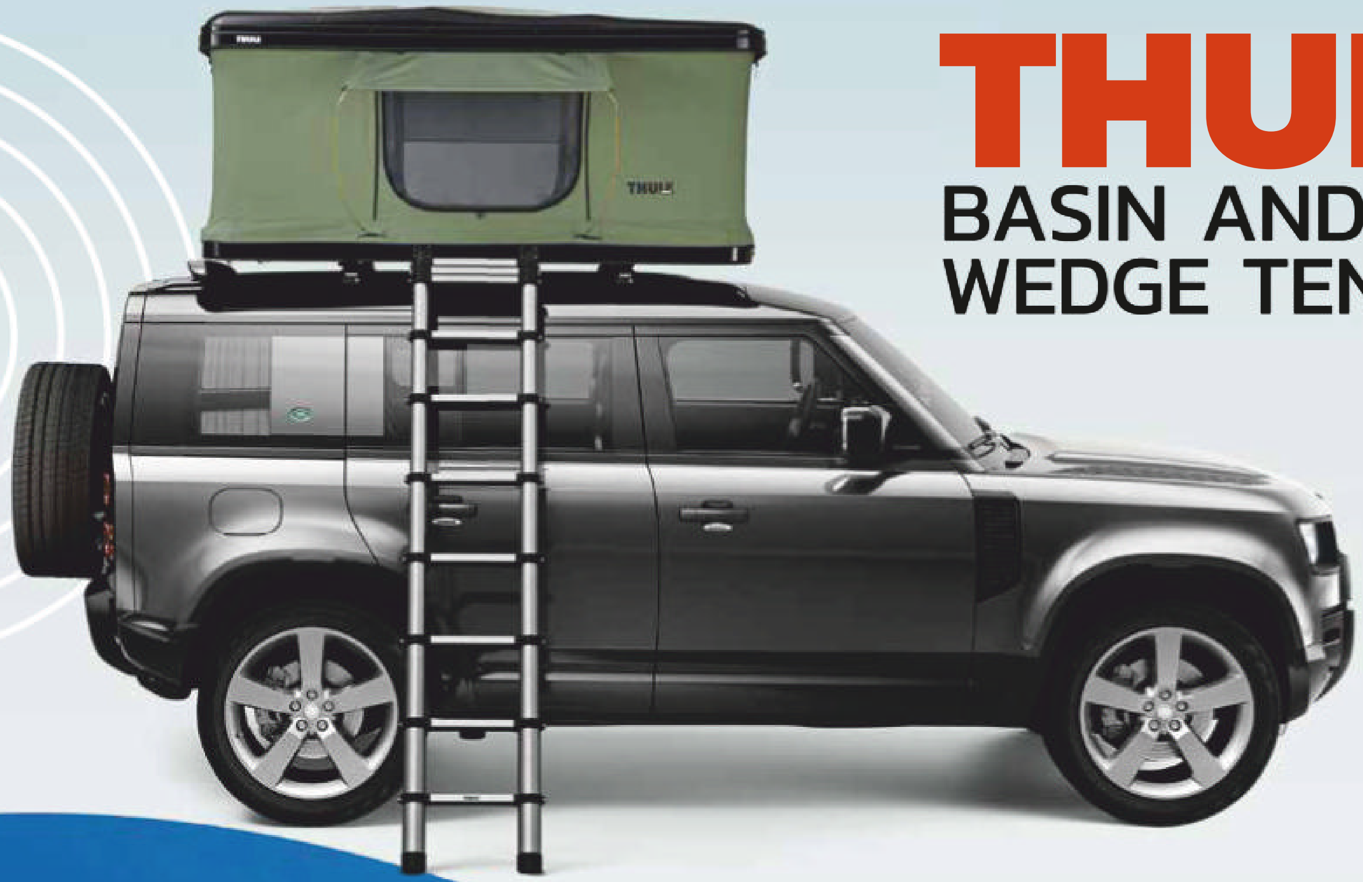
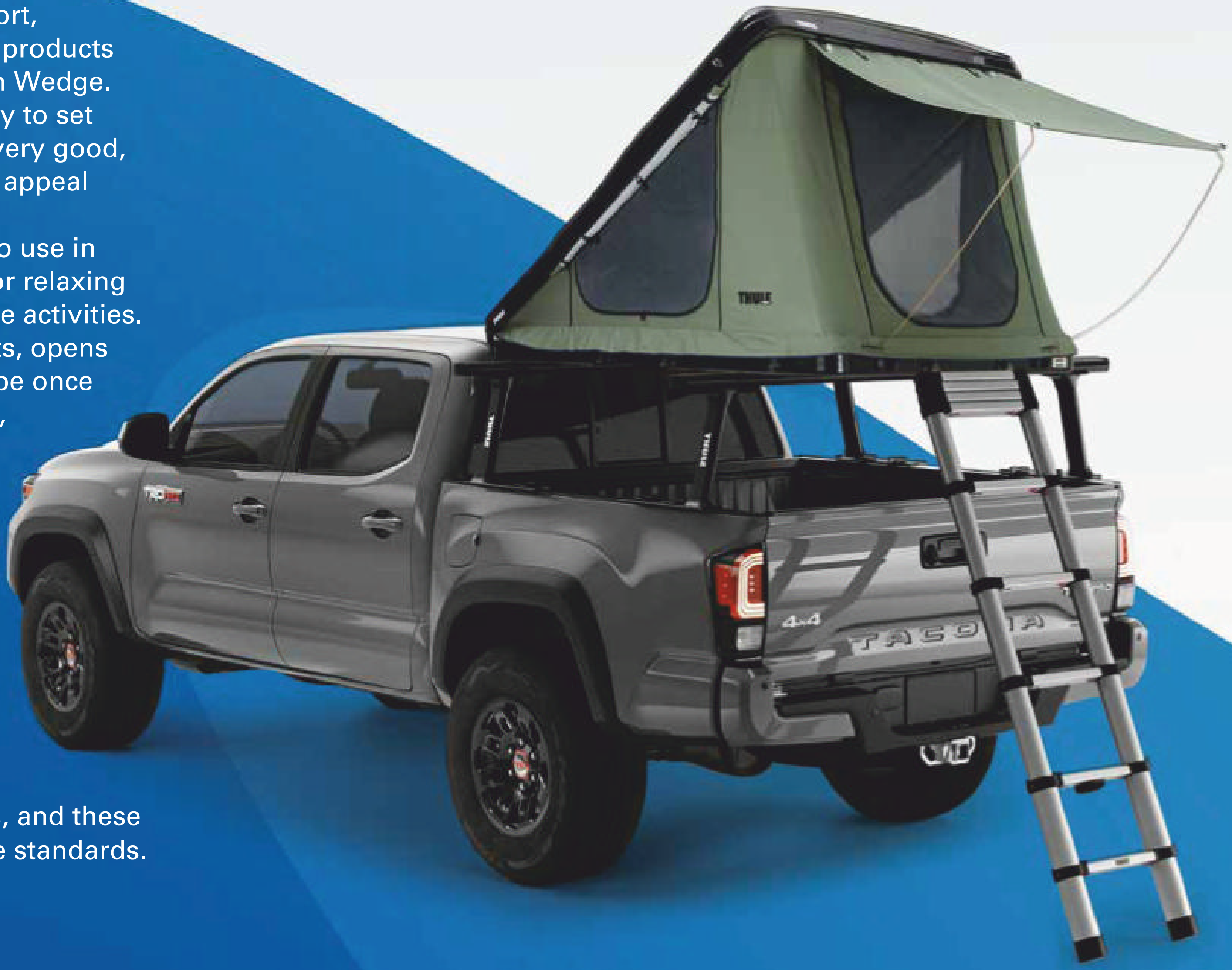


THULE

BASIN AND BASIN WEDGE TENTS



WHEN IT COMES to camping in comfort, Thule has created stylish roof-top tent products in the shape of the Basin and the Basin Wedge. Not only are these tents extremely easy to set up, and functional, but they also look very good, not at all detracting from the aesthetic appeal of your treasured vehicle.

Both tents can be set up and ready to use in under a minute, meaning more time for relaxing around the campfire or enjoying leisure activities. The Basin Wedge, as its name suggests, opens along one edge, forming a wedge shape once erected. The Basin deploys straight up, providing a spacious living and sleeping area. Both tent options are designed for two people.

Closed and packed away, the hardshell cases measure 213.4 × 140 × 32.5 cm, and they weigh 71 and 80 kg respectively. Each package includes a tent, tent base, mattress, telescoping ladder, and rainfly.

The Thule brand is synonymous with stylish designs, impeccable build quality, and highly functional products, and these two roof-top tents certainly meet those standards.

RRP R68 999 (Thule Basin Wedge)
RRP R69 999 (Thule Basin)
thulestore.TT

HYPERICE

HYPERVOLT GO 2

If you're familiar with any sort of intensive physical activity, you'll also be familiar with muscle stiffness and, we're afraid to say, injury. Even sitting at our desks for extended periods – and yes, we know all about that – can result in stiff neck muscles, uncomfortable lower backs, and tight hamstrings.

Help for these conditions comes in the form of the Hypervolt Go 2, a highly portable percussion massage device that's been engineered to treat various muscular body ailments. Made from durable plastic, it's highly durable, and its ergonomic shape makes it easy to hold as you treat different areas of your body. To do that, you charge it up (a green light around the base of the handle tells you when it's ready), and then choose one of three massage speeds. It comes with two head attachments, the broader one for larger muscle groups, and general massage, and a pointier one, to access more specific areas and deeper tissue.

You'll quickly get the hang of using it; just be aware that taking it over bone or less fleshy areas can be a bit uncomfortable. Several minutes of use should be enough to dissipate built-up lactic acid, post-workout, and help to get blood – and in turn, nutrients – flowing through stiff or injured areas.

It's compact, weighs less than 700 g, and a full charge lasts two to three hours. These factors make it ideal to take with you to the gym or sports field, as an effective remedy for aches and pains associated with training and physical performance.

RRP R3 999

hyperice.co.za

INSTANT POT

PRO 10-IN-1 SMART COOKER

Raise your hand if you've also been a bit terrified to try out a pressure cooker… Thankfully, the old days of exploding pots are long gone, and today's pressure cookers are high-tech electronic devices, with the Instant Pot brand leading the way.

While the Instant Pot Pro's many warning signs might seem as intimidating as its controls, it's actually a gadget that's a true ally in the kitchen. Once you get over your initial fears, you'll come to love how quickly and efficiently the smart pot works. While air fryers are great for crisping things up without excessive oil, and slow cookers are ideal to leave alone to do their thing while you're out for the day, the Instant Pot Pro is all about being faster and smarter.

If you're often short on time, you'll cherish this multi-talented appliance that not only pressure cooks, but also steams, bakes, sautés, sterilises, makes yogurt, and more. As an added benefit, researchers are now saying it's actually a healthier food-prep option. Why? Because faster cooking times give nutrients less time to escape and lower temperatures mean that the nutritional structure of food is retained.

There are a few things to learn when you first start using it, such as understanding how to vent the pot (which is effectively releasing steam), and when you can proceed with the lid on (or off), but once you've got to grips with the different techniques, you'll find this is an intuitive and highly efficient way of preparing food.

RRP R3 999

yuppiechef.co.za

Instant Pot
05:20

MEACOFAN
1056P PEDESTAL AIR CIRCULATOR

Who thought it was possible to fall in love with a fan? Well, we got to spend some hot summer days with the MeacoFan 1056P, and that's exactly what happened. It looks like a standard – if not somewhat sleeker – pedestal fan, but it's much more than that. It can move a prodigious 1 056 m³ of air around every hour, and it does this very quietly – the noise level starts at just 20 dB. It has multi-directional 3D oscillation, which, simply put, means it can move from side to side, up and down, or both.

The fan has four modes: normal, natural, sleep, and eco. Normal is, well, normal, but the other three are rather interesting. In natural mode, the airflow replicates a breeze, alternating between weak and strong, just like a natural breeze outdoors. In sleep mode, the speed of the fan decreases by one level every 30 minutes, facilitating a good night's rest. When set to eco mode, the higher the room temperature the faster the fan speed, which is smart, and energy efficient, too. You can opt to leave it on without worrying whether it will devour kilowatts of electricity. One of our favourite details is its handy remote. Unlike most other fan remotes, this one is magnetic, so you can attach it to the centre of the fan and not misplace it. It might seem like a minor feature but it's something you'll grow to rely on fairly quickly. As fans go, this is one of the best on the market.

RRP R3 499

solenco.co.za

NIIMBOT
B21 THERMAL LABEL PRINTER

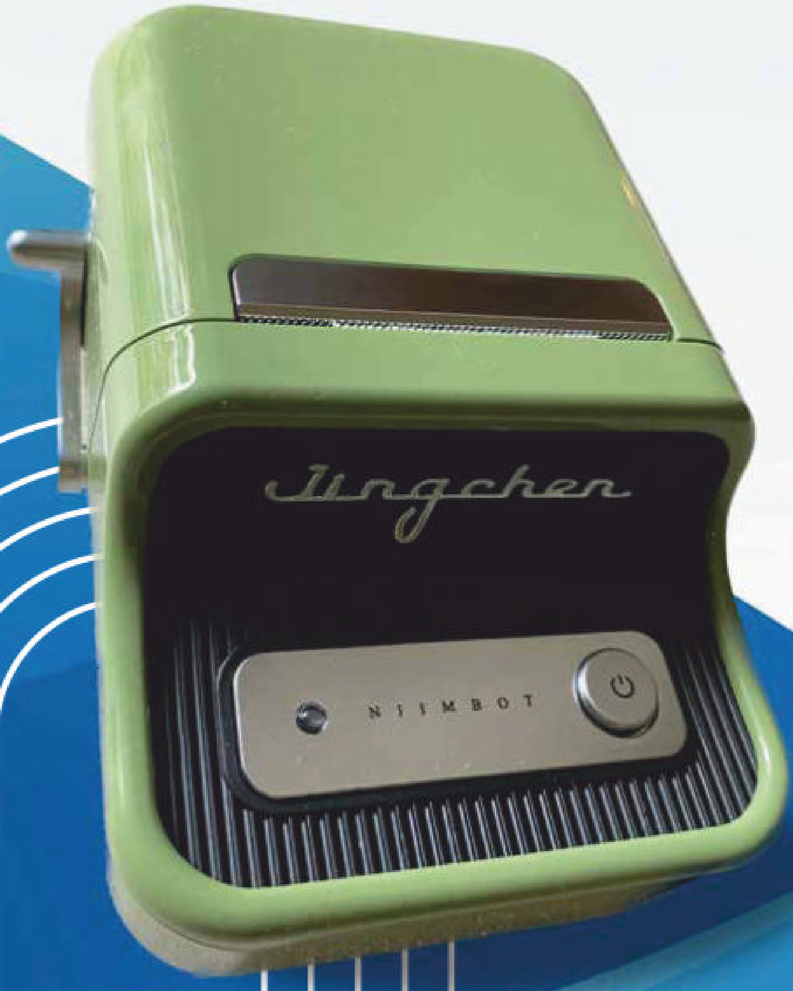
Modelled after a retro cash register, Niimbot's B21 thermal label printer is a captivating piece of tech. It's portable and small, so much so that it will fit into the palm of your hand. And this isn't any old-school label printer. The B21 is thermal, which means it doesn't use ink and only prints black.

It works via Bluetooth alongside an app, and has a rechargeable lithium-ion battery inside. While the B21 does come with some basic white labels, you can mix things up by buying a range of different ones – plain, transparent, or themed, and in different shapes and sizes. Loading new labels is very easy, made even more so because the printer features a chip that automatically identifies whichever shape label you've popped inside. Once connected to the app, customise your label by adding text or images. And if you're using the B21 for business, elements such as barcodes, QR codes, and serial numbers work too. When you're ready to print, a water- and smudge-proof label is produced in seconds.

No matter if you're a small business owner, busy parent, stationery addict, or simply crazy about labelling everything and anything, you won't be able to resist this ingenious little device.

RRP R1 399

keaistore.co.za



ASUS ZENBOOK PRO 16X OLED

The Zenbook Pro 16X OLED from ASUS is an ingeniously designed, future-proof laptop. It's a unique machine to use, too, and that's something you'll notice from the moment you unbox it.

These days, it's not uncommon to buy a stand that elevates your laptop at an angle that's more comfortable for typing. ASUS has taken this concept a step further, with a keyboard that rises seven degrees. This indeed makes for a more ergonomically comfortable typing experience, but it also plays a role in the smart cooling mechanism when you're operating power-hungry tasks. And this is only a part of one of the most advanced cooling systems (called IceCool Pro) that we've seen.

Adjacent to the trackpad is the 'ASUS dial', a circular button that provides additional creator functionality. The Zenbook Pro 16X really boasts everything you could want, and then some. Its full list of specs is mind-bending, and almost too long to recite, but highlights include dual-band WiFi 6E, Bluetooth 5.2, a 1080p webcam, six speakers, an oversized haptic touchpad, Dual Thunderbolt 4, and a massive 96 Wh battery.

While the price tag is high, this is a powerhouse device featuring premium build quality, an Intel Core i9 processor, and an immaculate OLED display. ASUS has put a lot of thought into the features creators want and need, and all of these have been included. Nothing feels gimmicky – it all comes together in a slick, high-performance package.

RRP R64 999
asus.com/za

ASUS Zenbook Pro
OLED

OWL LABS MEETING OWL PRO CONFERENCE CAMERA

Are you still working remotely from home? Perhaps your company is using some kind of hybrid model that embraces video conferencing? The pandemic is pretty much behind us but that doesn't mean online meetings are going anywhere. And, someone will always be accidentally on mute.

If you're going to be embracing the video-call life, the best way to do it is with a device that makes it as immersive and seamless as possible, and that's where the WiFi-enabled Meeting Owl Pro comes in. As its name suggests, it looks like an owl, especially when its eyes light up. And the likeness makes sense, because, like owls, this device has brilliant 'hearing' and vision (and, of course, it's made by a company called Owl Labs).

Bird attributes aside, when you're separated from your colleagues, this plug-and-play-ready 360° video camera has eight microphones and a speaker to replicate that in-office experience. It has the ability to automatically zone in on who is speaking, zooming in and framing the face of the person. Cleverly, it integrates easily with all the popular video-calling apps and team-working programmes. The camera-microphone combo makes live streaming easy, and should you need it, there's a tripod attachment port. The Meeting Owl Pro is versatile and practical for the modern remote worker … and hoo doesn't love an owl?

RRP R25 728
makro.co.za

alarm
VIBRATION DETECTION MODULE
STATUS
OUTPUT
RELAY
RX_IN
www.disrupter.co.za

V-ALARM

It's an unfortunate reality that we need to protect our valued property and assets from theft, tampering, or both, so finding the most functional and efficient equipment to achieve this is key. The V-ALARM ticks these boxes… It's an innovative vibration detection module that can be used as a stand-alone device, where no additional security system is required, or as part of an existing security or communication system, bolstering their effectiveness.

When fitted firmly in the chosen location, it monitors for vibration, movement, or tampering, and if any of these are detected, it creates an alert on an alarm output channel and its built-in relay output. Applications are extremely broad, but it's commonly fitted to slide- and swing gates, electric-gate motors and home security gates, solar panels, garage doors, caravans, trailers, motorbikes and boats, as well as power distribution boxes and mobile generators.

Installation is an easy do-it-yourself process, and the vibration sensitivity is adjustable. On standby mode, while no vibration is being detected, current consumption is around 1 mA. Because of this, it can be powered for many months using a 12 V 7 Ah battery, before recharging needs to happen. This makes it an appealing solution for remote sites, such as farms, warehouses or rural plots. (V-Alarm is stocked by Regal Security.)

Price on request
brendan.pillay@regalsecurity.co.za; info@disrupter.co.za; disrupter.co.za

XIAOMI
MINI MASSAGE GUN

What traits make for a good massage gun? For Xiaomi, it's amplitude, frequency and force. And with this particular 47 mm mini model, you can add in portability and price, too.

Massage guns are quickly becoming the go-to home device for fitness enthusiasts – they can work wonders when it comes to relieving muscle soreness by breaking down lactic acid build-up. Even if you're not an athlete and typically sit at a desk all day, percussion therapy is a good way of getting rid of stress, improving blood flow, and reducing inflammation.

With three different speed modes (1 800 rpm, 2 400 rpm, and 3 200 rpm), three interchangeable heads, and intelligent power control, Xiaomi's Mini Massage gun is great for on-the-go deep-tissue massage. The different head attachments target various parts of the body, and the high-speed and high-torque brushless motor can generate up to 570 Nm of force with a frequency of 3 200 rpm. Practically, it can reach muscle tissue that's 10 mm deep, quickly easing tightness and fascia tension. It has a pressure indicator which provides real-time feedback, so even if you press hard, it gives a constant power output with a low vibration amplitude.

It's wireless, so charging is necessary from time to time, via the cleverly hidden Type-C charging port. But, on full capacity you can get a good five hours of battery life, more than needed for several thorough home therapy massage sessions.

RRP R1 950
mifitness.co.za

UNDER ARMOUR

RISE 4 AND MERIDIAN

THERE'S NO BETTER WAY to kick off the new year than with a solid fitness training plan. And fortunately, Under Armour's research and development team has created a selection of technical gear to make you as comfortable as possible, while you get your sweat on.

The Meridian range of apparel boasts specially engineered fabric that's soft against your skin, while still retaining excellent moisture-wicking properties. The garments are lightweight, breathable, and stretch in multiple directions, so you'll never feel constricted during your weighted squats, lunges, burpees and push-ups. The Tapered Pants and Full-Zip Jacket are perfect for those chilly early mornings, or for your warm-up sessions.

The UA HOVR Rise 4 Training Shoes feature Under Armour's unique Tribase outsole, which delivers flexibility and stability as you progress through your training plan. The cushioning aids explosiveness, a dependable ally when taking on ladder drills, box jumps, and side shuffles. The breathable upper mesh is abrasion resistant, and the moulded TPU heel-to-midfoot strap keeps your heel planted against the inner sole, and enables forefoot mobility.

These new products are a culmination of Under Armour's constant and exhaustive product development processes in the fitness and training realm, so you can approach your new exercise regimen with confidence and in comfort.

RRP R2 299 (Men's UA HOVR Rise 4 shoes)
RRP R1 199 (Men's UA Meridian Short Sleeve)
RRP R2 499 (Men's UA Meridian Full-Zip)
RRP R1 999 (Men's UA Meridian Tapered Pants)
underarmour.co.za

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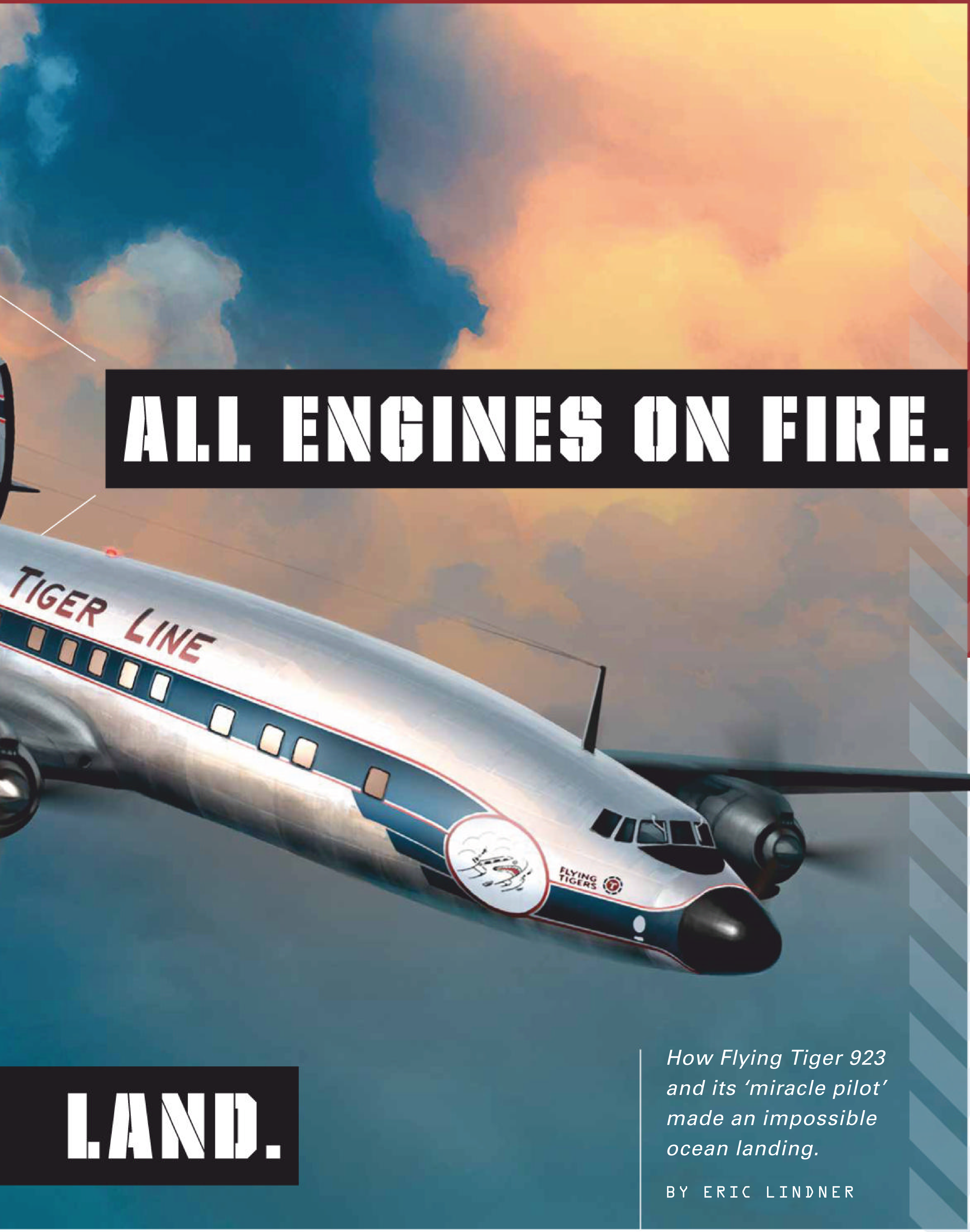
6 METRE WAVES.

N6917C
FLYING
H

1 500 KM FROM


TIGER LINE
FLYING TIGERS

ALL ENGINES ON FIRE.

LAND.

How Flying Tiger 923 and its 'miracle pilot' made an impossible ocean landing.

BY ERIC LINDNER

Eric Lindner's book Tiger in the Sea: The Ditching of Flying Tiger 923 and the Desperate Struggle for Survival *tells the story of pilot John Murray's 1962 lifesaving 'ditch' of an L-1049H Super Constellation in the North Atlantic Ocean. The barely controlled water landing with 76 passengers and crew members on board captivated the world at the height of the Cold War. Newspapers from London to Los Angeles ran breaking updates of the crash's aftermath, and President Kennedy received hourly updates concerning the fates of all involved.*

Lindner conducted dozens of interviews with survivors and eyewitnesses to write Tiger in the Sea. *His account is definitive, unearthing details and insights from Murray and others that reveal the full extent of the event's unprecedented danger, as well as Murray and his crew's miraculous airmanship and extraordinary ingenuity.*

Here, read an exclusive adaptation from Tiger in the Sea. →

PREVIOUS SPREAD: COURTESY JOE WIGHT

AS FLYING TIGER 923 SLICED THROUGH THE DARK SKY OVER THE ATLANTIC,

a thousand miles from land on the way to Frankfurt from Newfoundland, a red flash on the instrument panel caught Captain John Murray's eye: fire in engine no. 3; inboard, right side. The 73-ton Lockheed 1049H Super Constellation had 76 people on board, but the 44-year-old pilot from Oyster Bay, Long Island, wasn't rattled. He'd survived back-to-back plane crashes as a flight instructor in Detroit, Egyptian anti-aircraft fire as a black ops freelancer, and several overwater engine failures as a commercial pilot. Murray knew the most likely explanation for the signal was a transient electrical malfunction – the aircraft's fire-detection system was notoriously finicky – but still, Murray was puzzled: There was no alarm bell to go along with the flash. His log books accounted for 20 years of fire warnings, but zero entries spoke of a transient flash without an accompanying alarm.

Murray sat in the left cockpit seat, beside first officer Bob Parker. Navigator Sam 'Hard Luck' Nicholson and flight engineer Jim Garrett sat behind them. The flight deck was a claustrophobic clutter of manuals, personal belongings, floor-to-ceiling electronics, and cigarette smoke. To eliminate the potential for lethal drag, Murray instructed Garrett to feather engine no. 3, then stand by to discharge fire suppressant.

Garrett pulled the throttle back to idle and feathered the engine's propeller blades so they were parallel to the slipstream, then he cut off the fuel-air mixture control to disable the troubled engine. A bell clanged, and slumbering passengers jolted awake – it was a fire. Outside, crew members and passengers could see the flaming engine oil and white-hot steel fragments shooting from the no. 3 engine's exhaust stacks. The pyrotechnics lit up the sky.

Garrett raised his voice above the alarm bell: 'Ready to discharge, Captain.'

'Fire one bottle,' Murray said.

'Copy that.' Garrett lifted the small red spring-loaded aluminium cover labelled eng. fire dhg., moved the switch to the discharge position, and shot an extinguishing agent into the no. 3 engine. The alarm stopped. The fire light on the control panel went dark.

* * *

ACCORDING TO AVIATION SAFETY NETWORK statistics, which standardise accidents by passenger-miles flown, when Flying Tiger 923 took off on 23 September 1962, air travel was 100 times more dangerous than it is today. As for the Constellation ('Connie') series, nearly one of every five built between 1950 and 1958 had crashed or was otherwise out of commission. In March 1962, two Connies met ill-fated ends within hours of one another: One crashed in Alaska; the other disappeared somewhere over the Pacific.

Murray's Connie had rolled off a Burbank assembly line on 20 February 1958, but Howard Hughes had conceived the plane back in 1937. Because Connie used the same basic piston technology that powered wagons in 1844 (as opposed to the jet turbine first used in 1939), and because its Wright reciprocating engine wasn't as reliable as its chief competitor's Pratt & Whitney, Lockheed stopped producing Constellations a few months after Murray's plane was manufactured. Yet Murray himself still found a lot to like in his plane. He liked her range, ruggedness, and versatility, as well as her unique triple tail fins. He'd flown her 4 300 hours, often in dire conditions. She'd never let him down.

* * *

THE CRISIS SEEMED OVER BY 8:11 PM, THREE HOURS after takeoff. The fire was out, and any damage seemed contained within the exhaust stacks. Murray decided against shooting a second bottle of suppressant.

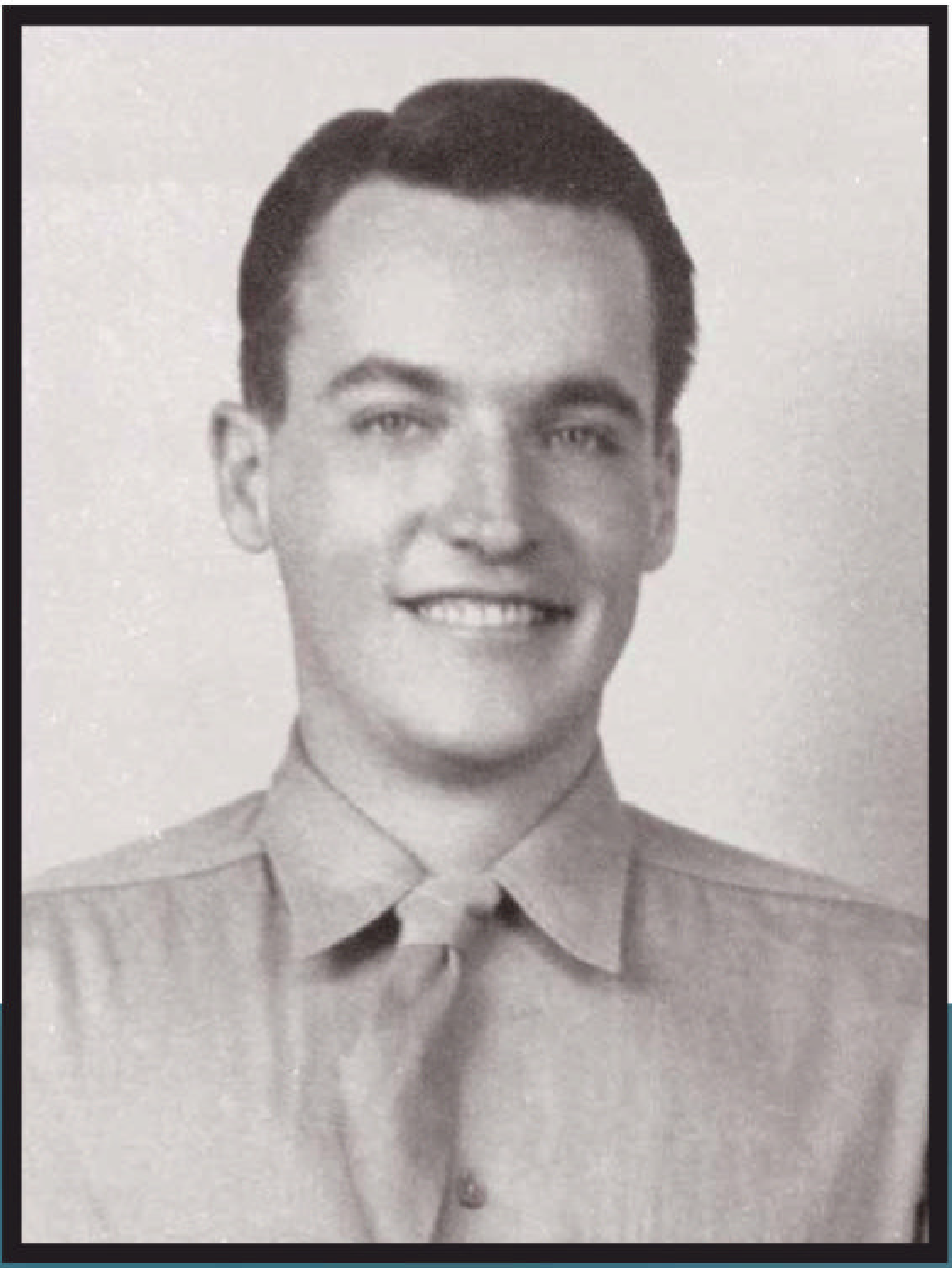
But flight engineer Garrett, a recent hire, had forgotten to close the no. 3 engine firewall. Moments after he closed the no. 1 firewall – on the left outboard engine – by mistake, his colleagues heard what they described as 'a shrill obscene snarl' from the left side of the aircraft. 'Runaway on number one!' Parker yelled.

The error had triggered a chain reaction: When the left outboard's hydraulic subsystem stopped pumping, blast air stopped cooling the generator, and fuel and oil stopped flowing to the motor and governor. This caused the propeller to spin out of control at close to the speed of sound. If the four metre blades were to break free, the projectiles could down the plane.

Murray muscled all the throttles back and decelerated Connie to 210 mph (338 km/h). Then he began easing her nose up, leveraging the air current into a makeshift brake. The blades slowed enough to allow Garrett to feather the no. 1. The crew averted disaster again.

But the plane had lost two of its four engines in seven minutes. Connie was 972 miles (1 564 km) from land,

Opposite: The Flying Tiger 923 plane in 1962, prior to its ill-fated flight over the Atlantic. **Below:** Captain John Murray.



THIS SPREAD: COURTESY FLYING TIGERS CLUB ARCHIVES (PLANE); COURTESY JOHN P MURRAY (MURRAY)

A 1962-era Super H Constellation cockpit.

COURTESY URS MATTLE AND ERNST FREI

and hundreds from the nearest ship. Murray knew he shouldn't try to make it all the way to Frankfurt, so he laid out three alternatives: pull up short at Shannon Airport, about 1 000 miles (1 610 km) closer; divert north to Keflavik Airport, closer still; or, the worst case scenario, attempt a ditching, what the FAA referred to as a 'controlled water landing'. Parker worked the radio, trying to keep the main rescue control centre in Cornwall apprised of Flying Tiger 923's co-ordinates and altitude, but he was struggling to communicate over the narrow, mid-oceanic high-frequency band. Garrett checked the performance charts to determine the cruising altitude that would cause the least strain per the current engine configuration and weight: 5 000 feet. They had enough fuel to reach Ireland.

But at 9:12 pm another red light flashed in the cockpit: fire in engine no. 2. Murray reduced power, Garrett feathered no. 2, the light went out, and the nerve-fraying alarm fell silent, but now the plane was flying on one engine. It couldn't do so for long, so Garrett reversed the feather on no. 2. The props realigned, and Flying Tiger 923 was back to two engines; thankfully, one on each wing.

After Hard Luck plotted a course for Ireland, Murray led a discussion on whether to deviate so as to overfly Britain's Ocean Station Juliett or America's Ocean Station Charlie. If ditching proved necessary, it would be much better to do so near one of the floating, well-provisioned outposts rather than in the middle of the open, frigid sea.

Deviating wasn't straightforward, however. First, while the British weather station was 160 km closer (400 km away versus 565 km for the American station), the US Coast Guard cutter *Owasco* was moored beside Charlie; it could travel to the crash site faster than crew members from either outpost in the event people needed rescue. Second, overflying either station could add another 280 km of engine strain. Murray directed Parker to establish contact with the *Owasco*, then asked the chief stewardess to lead her three colleagues in a ditching drill. Passengers handed over their pens, pocketknives, reading glasses, dentures, belts, and anything else that might injure them on impact, or puncture their life jackets or rafts.

The flight deck was hot, humid, and hectic. As the plane descended and settled into a cruising speed of 270 km/h, the uneven thrust from the full-powered right outboard and hobbled left inboard, coupled with the tacky altimeter and jumpy rpm, told Murray he wasn't out of the woods. The pilot considered dumping fuel to trim the plane's weight – the excess fuel beyond what they needed to reach Shannon was five per cent of the load – but the added buoyancy of an empty tank wasn't worth losing the cushion. He kept the fuel.

Yet another bell rang at 9:27 pm. A metallic grinding and screeching could be heard from the left side of the plane. Out the windows, a shower of sparks lit up the moonless sky. It seemed the no. 2 engine might explode at any second.

Murray throttled back on no. 2. The plane slowed, its nose lifted, the bell stopped ringing, and the fire light went out. But the pilot knew that if he kept throttling back, he'd never reach Ireland. He had exhausted all his options.

* * *

CIRCA 1962, THE US COAST GUARD DEFINED a 'successful ditching' to mean (i) the aircraft didn't sink immediately, (ii) it remained mostly intact, and (iii) a majority on board survived impact. No pilot had ever successfully ditched in such brutal conditions: a pitch-black night, winds gusting to 105 km/h, six metre waves. The North Atlantic seabed was a mausoleum for the remains of countless planes and ships, including the *Titanic* and dozens of Spanish galleons. For those aboard, hitting the water would feel like crashing on to a cement runway. Murray, a husband and father of five, knew his aluminium plane would most likely break apart on impact or sink in seconds. Land was 1 000 km away.

At 9:42 pm, another alarm bell rang out. The left inboard engine began shooting fiery blue-black carbonised fuel globules the size of a fist past the windows. Murray silenced the alarm but told his crew: 'Ditching seems probable now.'

Absent a significant change in the swells' direction, velocity, or height, Murray said he intended to fly into the wind, towards the swells, and touch down between two of them. His colleagues were perplexed. The manual

HOW TO DITCH A PLANE,

ACCORDING TO PHYSICS

by RHETT ALLAIN

Landing a plane on a runway is simple. A backward-pushing force, such as friction, between the tyres and the ground, or the engines' reverse thrust, slows the plane, while lift from the wings and the natural reaction force from the ground counter the downward forces of gravity.

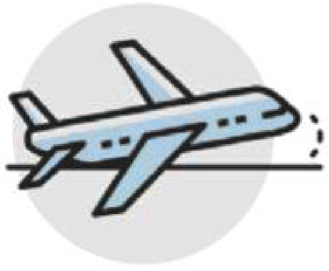
A water landing is similar, but pilots must also account for frictional forces from the water that can rotate – and wreck – the plane. If the plane's nose contacts the water first, the force will rotate the nose downwards and flip the plane. If one of the wings hits the water first, the plane can rotate in a spin. So a pilot needs to have utmost control over a plane's pitch, yaw, and roll – in addition to speed – to keep the plane level. Here's how to pull it off on flat water:

THROTTLE BACK TO JUST ABOVE STALL SPEED.

A slower plane receives less frictional force from the water – but stay above stall speed (this was about 180 km/h for Captain Murray's Connie), or you'll go from flying to falling.

ANGLE THE NOSE UP 5 TO 10 DEGREES RELATIVE TO THE WATER.

The best way to prevent a flip or spin is to touch down with the tail first. The resulting frictional force will actually pull the plane level. A steeper angle, however, might break the rear fuselage off the plane.



AFTER IMPACT, MAINTAIN LEVEL WINGS AND REDUCE ENGINE POWER.

Adjust roll by controlling the ailerons on each wing to keep the plane flat and prevent a spin as the fuselage and wings make impact. Let the backward-pushing force from the water stop the plane as you throttle down and maintain control, decreasing the lift from the wings.

read: 'Never land into the face of a swell or within 45 degrees of it.' These same instructions were also in all the US Navy tip sheets, Flight Safety Foundation bulletins, Air Line Pilots Association newsletters, and Civil Aeronautics Board accident reports. Murray explained: 'In almost every ditching training session, after a discussion of why it's better to land parallel to the swells, there'd always be an old-time flying-boat captain who landed his Sikorsky or Boeing into the swells.' The Coast Guard's instructions were 'sensible in theory,' he added, but they didn't apply to Connie's unprecedented situation. Because Murray felt the stiff winds at sea level would cut his speed and minimise sideways drift, the Flying Tiger captain said he intended to ditch like the flying-boat captains.

Where to touch down was the next question, but a 'height perception illusion', unique to ditching, hindered Murray's vision. For the human eye to process inputs, it needs a canvas of crisp, discrete focal points on which to paint a comprehensible picture. Seldom is this a problem when landing at an airport, since the trees, telephone poles, and air traffic control towers create a concrete referential pointillism easily processed by the eye. But during a ditching over active water, the sky merges into the sea, bleeds into the horizon, and plays tricks on a pilot's eyes, wreaking havoc with their depth perception. Illusions lead pilots to hit the water at the wrong spot or angle; too soon or too late; too slow or too fast.

As he dipped Connie below 2 000 feet, Murray could discern the direction of the swells. He estimated their height to be between 15 and 20 feet (4.5 and 6 m), the interval separating them 150 to 175 feet (45 to 55 m). Were he to hit a swell, it would act as a ferocious impact force-multiplier against the aircraft. At best, he had 3.5 m of wiggle room to lay down the 50 m plane. With winds buffeting Connie 4.5 to 7.5 m in every direction, and the possibility of hidden secondary swells beneath the whitecaps below, he'd have to perfectly calibrate the point and manner of impact.

Then, it started to rain like mad. But as the Moon emerged from hiding and lightened the sky, Murray's height-perception illusion dissipated and he could more clearly make out the distance between swells: about 60 m, crest to crest. That gave him an 11 m margin of error – for a plane travelling 54 m per second. The waves were high and powerful enough to snap Connie's wings off and send the four life rafts tucked in their bays to the bottom of the sea.

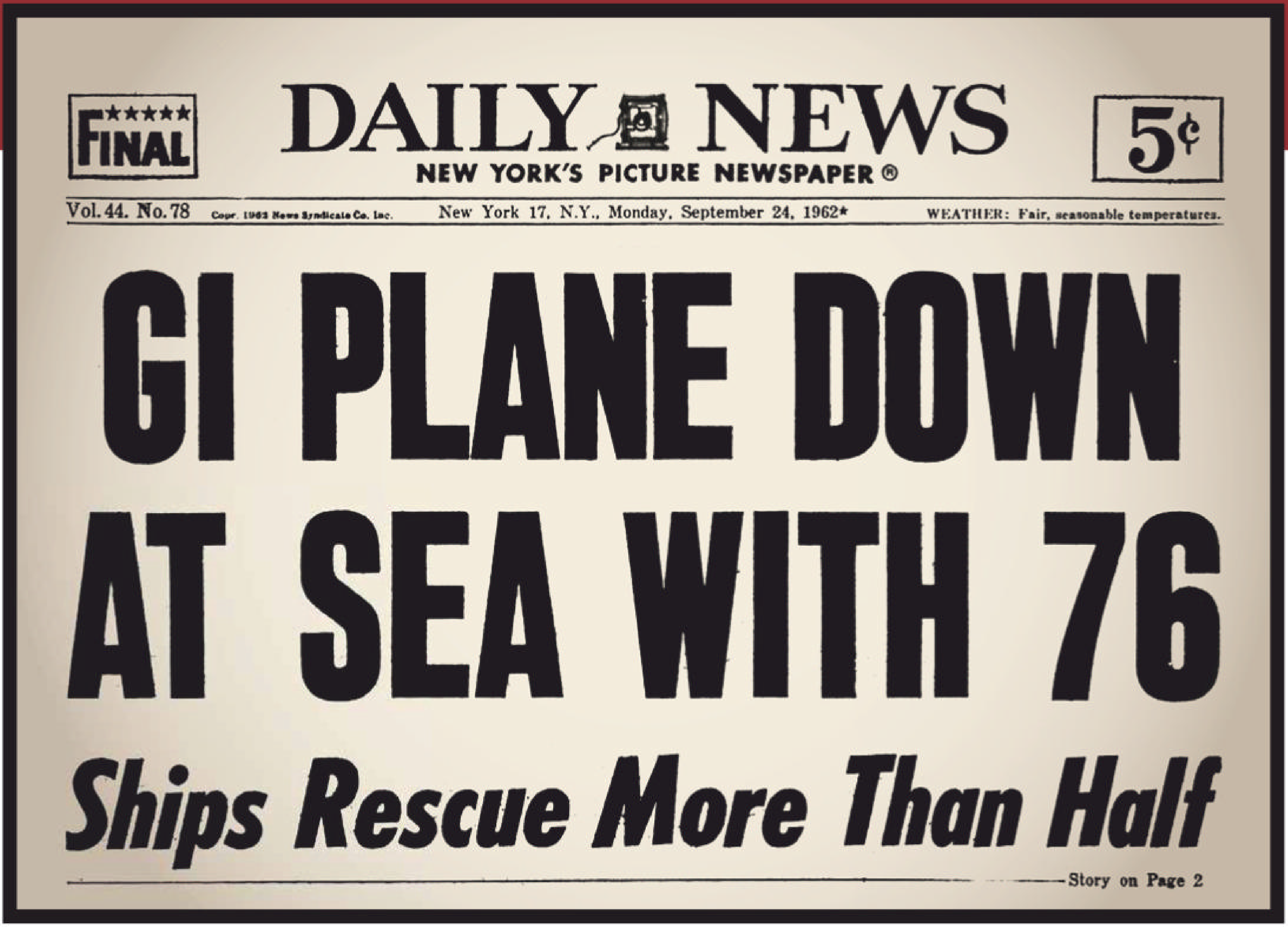
The optimal descent slope was 7.6 m per second, but Flying Tiger 923 was heading towards the sea at 10.5 m per second. Murray fought to flatten the grade, but gravity was tugging Connie towards the ocean. If he didn't elevate fast, they'd hit the water at a catastrophic angle and velocity.

He wrestled against the opposing winds, struggling to maintain an even keel. Were either wing to clip one of the powerful swells, Connie would flip into a horrifying cartwheel, breaking apart, sinking, and likely killing everyone. The lone working engine – the right outboard, no. 4 – billowed angry blue flames as it tried to do the work of four. No. 2's unfeathered prop rotated erratically at the mercy of the wind. As the landing lights illuminated his point of impact, Murray called out over the 121.5 frequency: 'Mayday. About to ditch. Position at 2212 Zulu Fifty-Four North, Twenty-Four West. One engine serviceable. Souls on board seventy-six. Request shipping in area prepare to search. Over.'

Below: A circa 1962 Super H Constellation fuel dumping and firewall junction box (located at a flight engineer's workstation).

FUEL DUMP
TANKS 1 & 2
FUEL DUMP
TANKS 3 & 4
EMERGENCY
SHUT-OFF
IGNITION
AUXILIARY CONTROL BOOSTER
ELEVATOR
RUDDER
PANEL LIGHTS
RADAR

COURTESY PETER W. FREY (BOX)



★★★★★ FINAL

DAILY NEWS

NEW YORK'S PICTURE NEWSPAPER ®

5¢

Vol. 44. No. 78 Copr. 1962 News Syndicate Co. Inc. New York 17, N.Y., Monday, September 24, 1962★ WEATHER: Fair, seasonable temperatures.

GI PLANE DOWN AT SEA WITH 76

Ships Rescue More Than Half

Story on Page 2

The *Daily News* front page on 24 September 1962, the day after Flying Tiger 923 went down.

NY DAILY NEWS VIA GETTY IMAGES

The plane hit the water at a speed of 195 km/h – 900 km from land.

■ ■ ■ ■ ■

ALL 76 PASSENGERS AND CREW MEMBERS survived the impact and evacuated the wreck. However, after seven nightmarish hours in the rough, bitterly cold North Atlantic, only 48 survivors boarded the first ship on the scene, a Swiss grain freighter. The remaining 28 died from drowning: many during a frantic, futile search to find the four missing life rafts.

Flying Tiger 923's sea crash was the world's top story for a week. In the US, news bulletins interrupted the massively popular *Bonanza* to give updates on the crash, rescuers appeared on *The Ed Sullivan Show* before an at-home audience of 40 million viewers, and in terms of column inches, the story received more newspaper coverage than astronaut John Glenn's Florida splashdown earlier that year. Anchors and aviators alike hailed 'the miracle pilot', but how was John Murray able to overcome so many mechanical problems, manage so many simultaneous crises, and do what most experts said was impossible?

First, 85 per cent of Murray's piloting since 1957 came at the helm of a Super Constellation, but he also effected water landings on seaplanes and amphibians (he held ratings in both). Second, his engineering training primed his decision-making to be anchored in physics, not convention. Third, he was a precise delegator and leader, with a clarity of purpose and serenity fostered by a deep personal faith. He didn't make reactive, survival-motivated decisions, but decisions based on a personal sense of responsibility for the 75 other lives on board. A pilot colleague once said about him, 'John knew he was expendable. It was the definition of what being a captain is all about: going down with your ship.' **PM**

Adapted from *Tiger in the Sea: The Ditching of Flying Tiger 923 and the Desperate Struggle for Survival* (Lyons Press; 14 May 2021).

I bought a GHOST

Brent Underwood owns Cerro Gordo, a mining town from the 1800s in the high desert of Southern California.

TOWN

This abandoned California mining village once had 400 buildings. Now I'm restoring the 20 that remain.

By Brent Underwood, as told to Clint Carter

IN 2018, BRENT UNDERWOOD SUBMITTED A WINNING $1.4 MILLION BID *on a network of dried-up silver mines in Southern California. The property includes 336 acres (136 ha) of high-desert terrain and the remains of a mining boomtown called Cerro Gordo, or 'Fat Hill'.*

After Covid-19 hit, Underwood moved from his home in Austin, Texas, to live at Cerro Gordo full-time. Now he's the sole inhabitant of a genuine Wild West artefact.

The day we closed on Cerro Gordo, my partner and I met the caretaker to receive the most preposterous key chain I've ever seen. There must have been 40 keys hanging off it. It happened to be Friday the 13th and my partner's birthday, so after signing the papers, we retreated to Cerro Gordo to celebrate.

The plan back then was basically the same as it is now: We want to turn the old mining town into an offbeat hospitality destination and artist retreat. Things just haven't run as smoothly as we'd hoped.

Originally we talked about soft-launching a few cabins on Airbnb by Halloween 2019, but logistical challenges, a catastrophic fire, and an international pandemic have continued to push that date back. Now here we are (in 2022), still not open for overnight guests, and for the past two years, I've lived at Cerro Gordo alone.

Don't get me wrong, the town is humming. Volunteers show up frequently to help me restore the old buildings, and brave travellers drive in over nearly eight miles of steep, rough gravel for self-guided tours. But it's a lot of work to put in without any serious income.

This isn't how I imagined my life, but I'm not complaining. Despite the challenges, I've never been happier. I feel a real connection to the town's Wild West history: Miners started settling Cerro Gordo in the 1800s, and Butch Cassidy is said to have spent time here hiding out from the law. I have a view of Mt Whitney on one side and Death Valley on the other, and every day I explore abandoned mines and hunt for artefacts left behind by the men who worked here.

The more time I spend at Cerro Gordo, the more I fall in love, and now when I leave to stock up on groceries or gather supplies, I immediately want to come back. But it's hard work bringing a ghost town back to life. Here are a few things I've learnt along the way.

LIFE WITHOUT WATER IS PRETTY MUCH TORTURE.

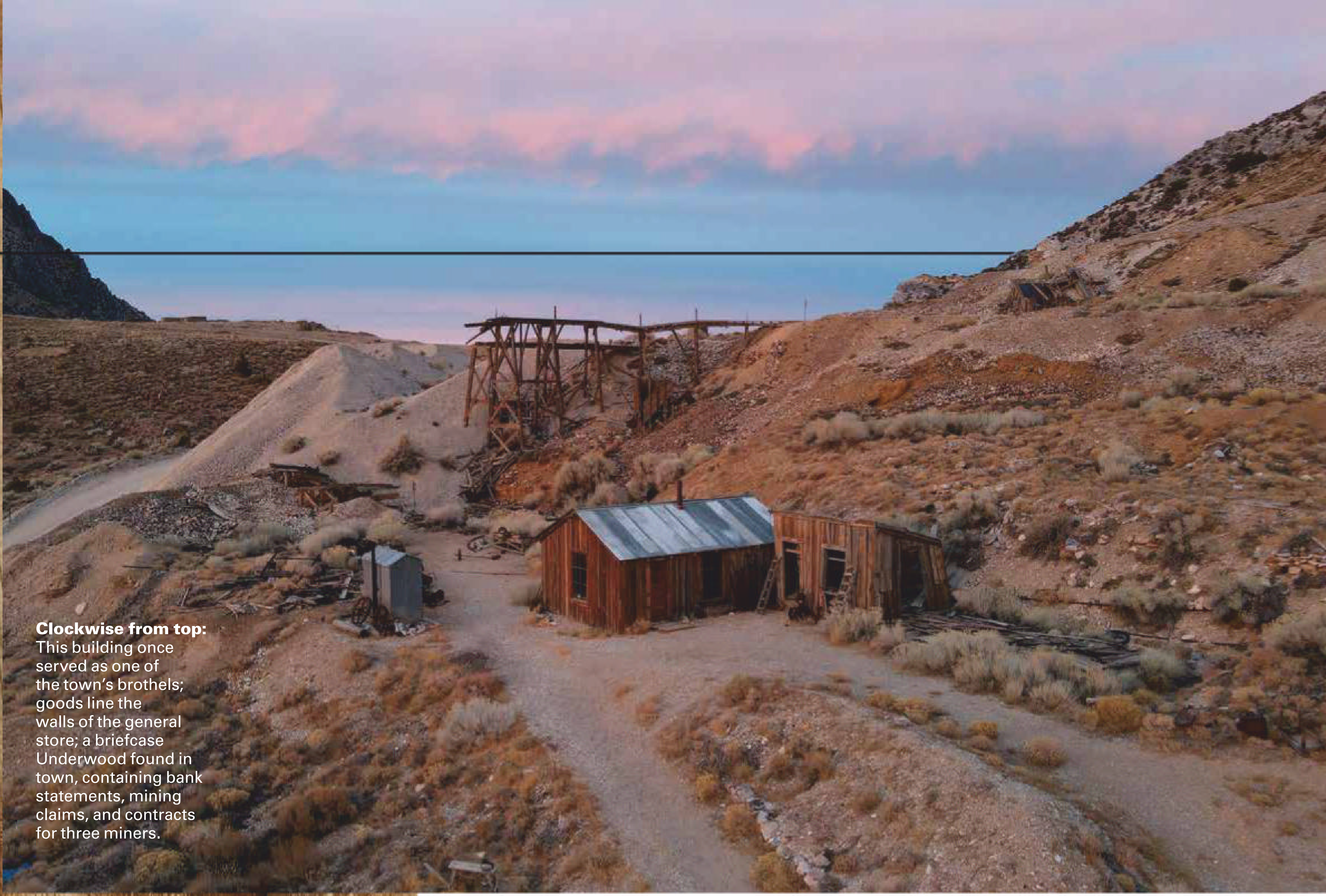
CERRO GORDO DRIED UP YEARS AGO WHEN Los Angeles redirected its water supply and drained Owens Lake, which used to sit just below the town. The initiative was part of the aqueduct programme that inspired the movie *Chinatown*, and I had to truck water up the gravel road in limited amounts.

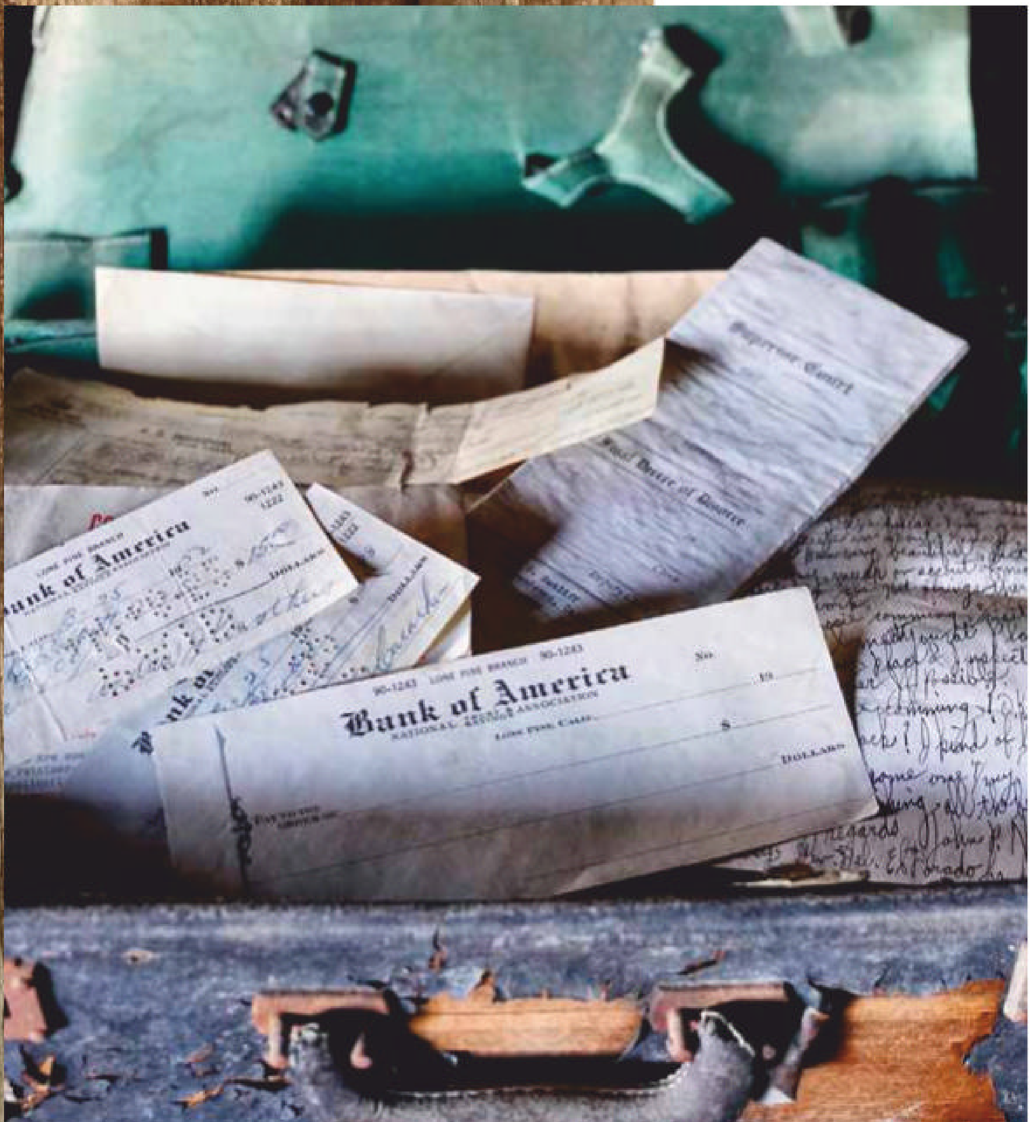
You can imagine life without running taps, but living it every day is another story. With no plumbing, I used an outhouse and washed my hands in a bowl. To shower, I warmed a rubber bag of water in the sun and then let it dribble down on me from above. I longed for a sink, a washing machine, and a garden hose.

I'd heard stories about water leaking into one of the mines. Legend had it that there was a sump 700 feet (214 m) underground, with an old pump that stopped working. The problem was, the lift to go down and inspect the situation is 150 years old, and almost everybody I spoke to told me it was too dangerous to use. Especially since there was no guarantee that water was still there.

But time wore me down, and I had to find out. So I put together a team with an electrician, a lift operator, and a Cerro Gordo old-timer who'd been down the shaft years ago. As the hoist started dropping us, the guy looked at me and said, 'Brent, you got to figure that every time you go down is your last.' The lift cable could break. The walls could cave in around us. I was terrified. It took nearly an hour for the rickety old lift to drop us 700 feet (214 m).

But when we arrived, we found it. The water was there. We swapped out the old chemical pump for a new one, and I now have running water into my personal cabin. The flow




Bank of America
Bank of America

Gordo Mines Co. Keeler, In

Clockwise from top: This building once served as one of the town's brothels; goods line the walls of the general store; a briefcase Underwood found in town, containing bank statements, mining claims, and contracts for three miners.

PHOTOGRAPHY: PREVIOUS SPREAD – COURTESY BRENT UNDERWOOD; GETTY IMAGES (BACKGROUND, I, NAILS); COURTESY BRENT UNDERWOOD (RIGHT)

HOW TO BUY YOUR OWN UNIQUE PROPERTY

Looking for your own Cerro Gordo? Start here.

LET PEOPLE KNOW YOU'RE LOOKING

A report from the analytics company GeoTab counts more than 3 800 ghost towns still standing in America. But they don't usually receive much attention when they hit the market, says Underwood. Weird property news generally travels fastest by word of mouth.

Before he discovered Cerro Gordo, for instance, Underwood told people he was looking for a challenging hospitality project. One day, out of the blue, a friend texted him the listing along with a note: 'LOL, this might be up your alley.' The friend was correct.

GO ALL IN

After contacting the broker, Underwood discovered that a hundred or so people had already expressed interest. So he entered a bid he couldn't afford: $1.4 million, all cash. It was 50% over asking price, and he committed to closing the deal in seven days.

'The problem was I didn't have even 10 per cent of $1.4 million,' he says. 'And no bank is going to lend money on a ghost town with no running water and no foreseeable way to generate revenue.'

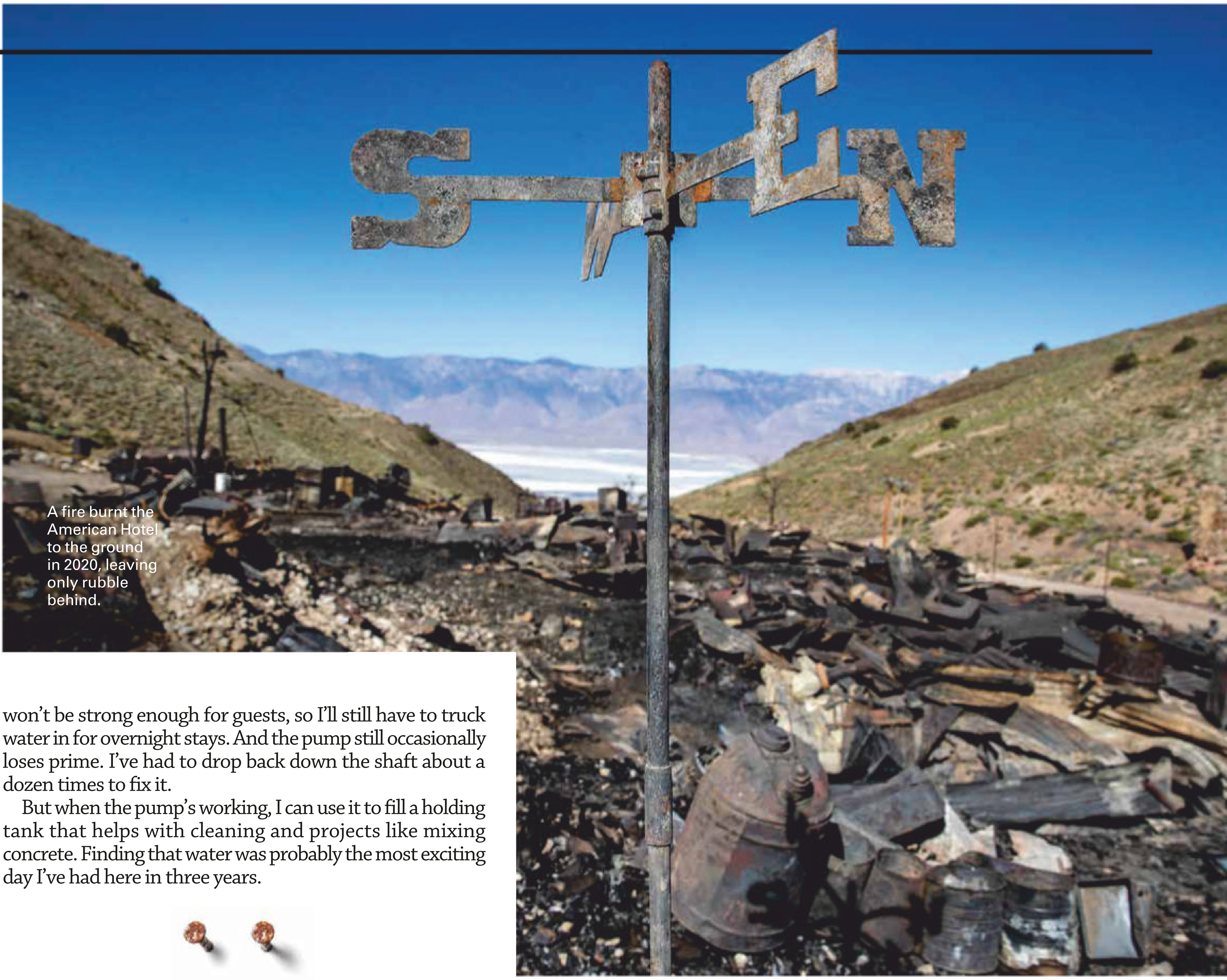
The seller accepted the offer, and Underwood wired over a non-refundable $50 000 deposit. Then he and his partner, Jon Bier, called everyone in their networks to raise money. They managed to hit the goal only through the help of a short-term hard-money loan that came in after 4 pm on their scheduled closing day. If the property's that special, that's the kind of commitment you'll probably need.

THINK BEYOND THE WILD WEST

Underwood wasn't looking specifically for an abandoned mining town. He just wanted something with a rich history, and if you take that approach, you'll find more inventory. 'Somebody just texted me a Craigslist listing for an old library in Vermont that has 50 000 books from the 1700s onward,' says Underwood. 'It has nine rooms, and it's potentially haunted.'

That, he says, is the kind of property with value beyond its rickety structure. 'People aren't interested in Cerro Gordo because of the old buildings,' he says. They're interested because it was the largest mining town in California, and it's the source of so much mystery and lore. 'If I were looking for another property, I would find one like that.'

Cerro Gordo has a number of cabins where miners would stay while they worked.


A fire burnt the American Hotel to the ground in 2020, leaving only rubble behind.

PHOTOGRAPHY: COURTESY BRENT UNDERWOOD (CABIN); BRIAN VAN DER BRUG/LOS ANGELES TIMES VIA GETTY IMAGES (FIRE); GETTY IMAGES (BACKGROUND, NAILS)

won't be strong enough for guests, so I'll still have to truck water in for overnight stays. And the pump still occasionally loses prime. I've had to drop back down the shaft about a dozen times to fix it.

But when the pump's working, I can use it to fill a holding tank that helps with cleaning and projects like mixing concrete. Finding that water was probably the most exciting day I've had here in three years.

* * *

FIRE IS A CONSTANT THREAT.

IN ITS HEYDAY, CERRO GORDO HAD 400 WOODEN buildings. Today it has just 20, and most of that loss is likely due to fire from lightning strikes or shoddy electricity.

In the summer of 2020, as we got close to opening a couple of the cabins for guests, I woke up to find the American Hotel, the crown jewel of Cerro Gordo, engulfed in flames. It was the result of too many amateur electricians tinkering with wiring over the years. Something sparked, and the old wood caught like kindling.

We were lucky it happened while nobody was sleeping in it, but we were devastated at the loss of our most prized building. We had to delay opening further to clean the mess and implement fire safety in the existing buildings.

A couple hundred years from now, I hope people think about the fire of 2020 as just another chapter in Cerro Gordo history. With our new plan, we're rebuilding the American Hotel as authentically as possible. We're replicating the interior and using 100 year-old period wood on the facade. But this time we'll have a sprinkler system. We'll have six rooms, and everything will be up to modern code.

* * *

EVEN GHOST TOWNS HAVE WIFI.

ONE OF THE NEARBY MOUNTAINS HAS A CELL TOWER, so I'm able to pick up spotty internet service using an AT&T hotspot. It's not enough to stream anything, but I can work my day job remotely – I'm a partner at a creative marketing firm. And I'm able to share Cerro Gordo with the world.

Left: Cerro Gordo in the late 1800s; **Above:** Underwood stands near some of the town's remaining 20 buildings. Most of the others have been lost to fires.

A couple of years ago, after a friend kept asking how it was to live here, I posted a few YouTube videos. My first one now has more than eight million views, and it caught the attention of some other big creators.

That's allowed me to help build some attention around the mining town, which will help when I eventually have the hotel open. FaZe Clan, which are like the Yankees of e-sports, came out and shot some video. And Sam and Colby, these paranormal guys, came out looking for treasure. One of them recommended that I start posting my daily mine adventures on TikTok. I followed the advice, and within a month I had a million followers. Now that number is over three million.

LOCAL PRIDE IS A VITAL RESOURCE.

LONE PINE IS ABOUT 25 MILES (40 KM) AWAY from Cerro Gordo, and further on up Highway 395, you come across Independence and Bishop. Some of the locals in those towns really want to see Cerro Gordo succeed. They grew up hiking the property and visiting the old buildings, so they understand the potential.

After the fire, some of those locals saw me struggling out here alone, and they just started showing up. Some volunteered time, and others offered equipment. The guy who owns the local tow shop lent me his Bobcat, and we had an architect do building plans for free. Once we started making progress, more people offered to help. A guy from Utah showed up to truck in concrete. It's incredibly inspiring, and we're making a tremendous amount of progress. We poured the 81 feet (25 m) of footers and hauled in 4 000 cinder blocks for the basement. Soon we'll begin framing, and with luck we'll be open for business in November.

THERE'S ALWAYS MORE TO DISCOVER.

THERE WAS A TIME WHEN I THOUGHT I'D BEEN to every mine on the property, but then I came across a 1960s report from the United States Geological Survey. It estimated there were 30 miles (38 km) of mines at Cerro Gordo. I've only seen about 20 per cent of that, so I figure I have about 24 miles (38 km) of mines left to discover.

You'd think mines would be easy to find, but they're not. One day the old-timer who helped me fix the water pump asked, 'You ever been to San Lucas?'

I hadn't, and for good reason. Years ago, it turns out, he purposely hid the trail that leads the way there. After showing me his first secret mine, he showed me five or six others that I never would have found exploring the area on my own.

That was a big breakthrough. But most of the time, I find mines with slow, patient searching. I start by scanning mountainsides from across the valley. I look for tailing piles, which are the mounds of rock deposited outside the portal, or entrance. When I find a pile, I pinpoint a nearby landmark that looks like a good spot to start my hike in, and then I head for that spot.

Often I arrive to find that the portal's collapsed. It's frustrating when you walk an hour to a mine, only to learn you can't enter. But as I've grown more comfortable with mine exploration, I've started to occasionally dig out the entrances. There are some mines where you can march right in, and others where you dig a hole and then squeeze yourself through.

But every mine is different. Take the Omega Tunnel. For that one, I spent two weeks digging with a loader and then blasted it with dynamite. But I still couldn't get in. So I spent another month or so excavating, and when I finally gained entrance, I discovered it was collapsed 200 yards in.

To go deeper, I'll need to start digging again. And I'm sure I will get around to that eventually, but there's a lot of other work to do around here. Nothing's ever easy, but that's what I signed up for. And I know it will all be worth it as soon as I'm able to share this town with more people. **PM**

Underwood has found lots of old mining artefacts in his explorations, including dynamite, liquor bottles, Levis, and carbide tins.

PHOTOGRAPHY: COURTESY BRENT UNDERWOOD (1800S, PORTRAIT, MINE); GETTY IMAGES (BACKGROUND, NAILS)

BY **STEVEN MARK SALOWSKY**

PHOTOGRAPHY BY **CHRISTOPHER CHURCHILL**

WE BUILT THE WORLD'S FIRST V-8 TESLA

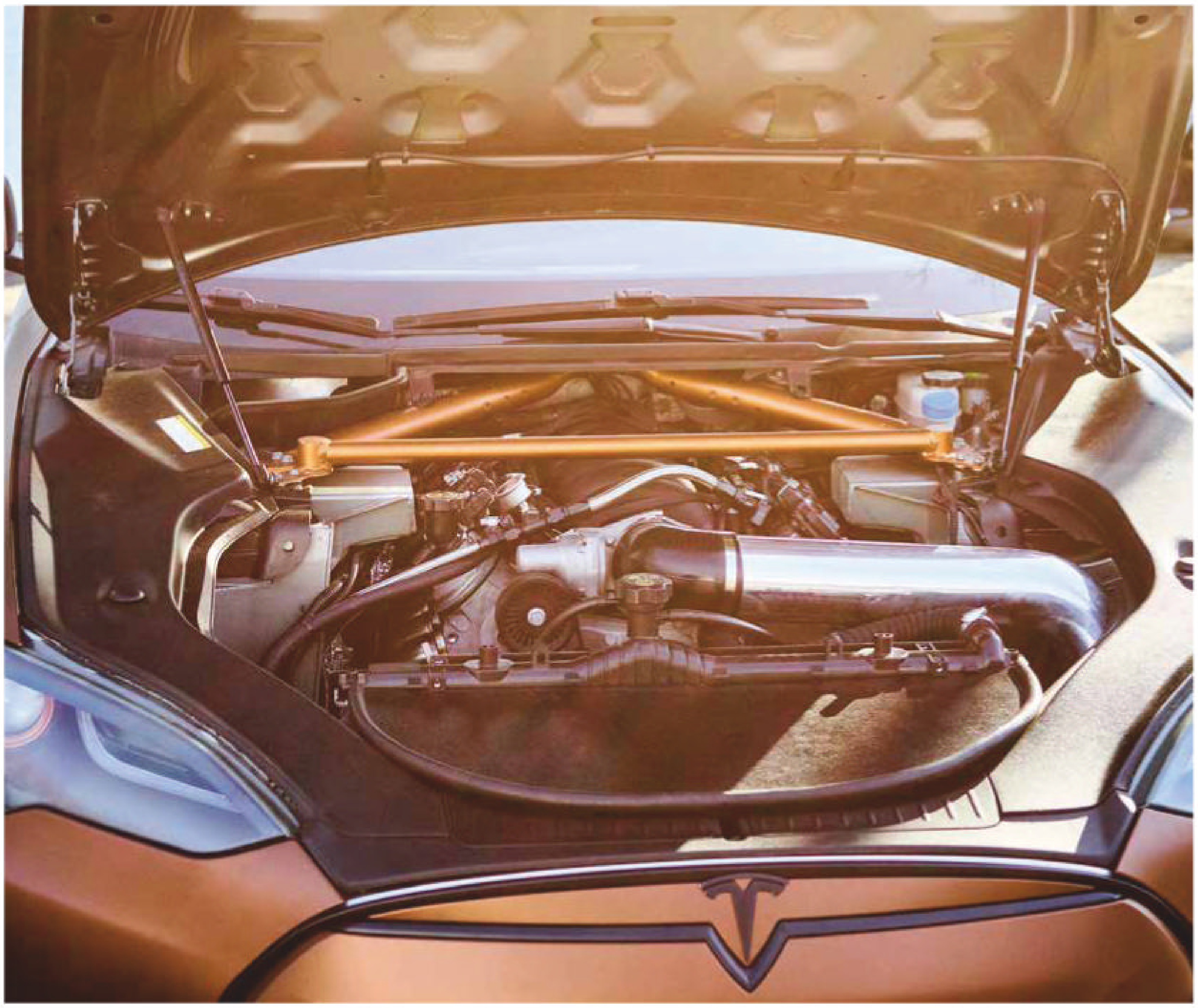
THE RICH REBUILDS TEAM HAD A DEAD MODEL S. THEY FIXED IT WITH A CAMARO ENGINE.

Our 2015 Tesla Model S and its LS3 V-8, pulled from a wrecked 2011 Chevrolet Camaro SS.

SINCE THE DAWN OF TIME, WE'VE WANTED TO DISPLAY A FEATURED CAR AT SEMA.

Our team (from left): Bryan Maynard, Steven Salowsky, Rich Benoit, Chad Hrencecin and Joshua Dodge.

We fabricated a triangular brace instead of a strut bar (above the engine) to add rigidity to the frame.



THE SPECIALTY EQUIPMENT Market Association trade show in Las Vegas is extravagant, it is inspiring, it is perhaps the greatest automotive battle for superiority you'll ever witness. It's an annual gathering for every somebody in the car world to show off the fanciest thing they can create on four(ish) wheels.

My business partner, Rich Benoit, and I thought we finally had something radical and bold enough for the event. We didn't just want to exist there... we wanted to steal the show.

That also meant we needed a car that could actually move under its own power. Most of the cars at SEMA get pushed on to the expo floor, but nobody's happy about it. The shame of an unfinished ride is something to avoid at all costs. And yet with 30 hours until our transport truck arrived, we were approaching the city limits of Shamesville.

After two years of patiently converting a Tesla to an internal-combustion-engine muscle car – we'll get to why on Earth anyone would do this – we were down to just hooking up the fuel lines but were caught waiting for fitments to arrive in the mail. And they weren't going to make it in time.

* * *

Rich and I have been revitalising Teslas for about six years now. It started when Rich, an intrepid tinkerer, wanted a Tesla Model S but didn't think it was reasonable to pay $100 000 for one. His solution: Take a couple of salvaged Teslas and put them together. Simple, right? Start with a flooded electric vehicle – good for its shell, not its corroded batteries – and wait for a second Tesla with a battered shell and a good set of Duracells. After a year and a half of wrenching, our first fully functional electric car emerged for a total of $6 500. It also launched our YouTube channel (Rich Rebuilds) in 2017, featuring odd and eclectic EV projects, and eventually the Electrified Garage, our sister company that performs EV maintenance, repair, and conversions for the public.

After a couple of years, we were running out of Tesla projects and started building up cars that we simply wanted to enjoy. We resurrected a BMW i8. We gave a 1932 Ford Model A an electric powertrain from a crashed LAPD motorcycle. And we restored a neglected twin-turbo Audi RS7 – too beautiful not to save. Not every project had a battery, which upset the die-hard EV hive, but we love all things automotive.

All the while we were buying up salvaged Teslas (we're up to 17 in various stages of destruction). Despite our well-documented love for Tesla, the feeling isn't mutual. We

After too much debate, we opted for a forward position S1 Sequential shifter.

Ringleader Rich Benoit, laughing like he's reading angry YouTube comments from Tesla stans.

buy so many wrecked Teslas because the company won't sell us its house-manufactured batteries and motors. We know it's (mostly) not personal, because Tesla won't sell to anyone, not even a certified tech who's outside the company.

Usually that's not a problem, because insurance companies act like touching even a slightly damaged Tesla would result in widespread hair loss. Fools. They write the cars off as a total loss for salvage, and then we rehabilitate each Tesla for a tidy profit or part it out.

We're never sure what we've bought until we can check out the internals, but most of these are low-risk purchases. There was one, however, that was a true lemon. This 2015 Tesla Model S P85D looked like it was in great shape and could be more than another parts car. We happily put down $23 000, only to discover that the insurance note of minor water damage actually meant it had gone for a swim. Just like a cellphone dropped in water for too long, the submerged electronic boards made this vehicle a very expensive paperweight that no amount of rice could revive. Worse, we had a battery and motor shortage for this model because it was particularly safe and seldom crashed.

So we had this gorgeous vehicle with barely a scratch on it that could not move under its own power – because there was none. So a terrible idea was born.

Well, Chevy would sell us a motor. It was a simple statement. It was also blasphemy, sacrilegious to Tesla's environmental cause. We laughed for a good long while, and were then overtaken by deafening silence. One should *not* put a petrol engine in an electric car. But we knew we had to do it.

We'd toyed with the idea when Tesla first emerged on the scene, and we knew we weren't the only ones who thought of jamming a gasoline hog in the frunk – the front trunk. In fact, Joshua Dodge, our welder on this project, had bombarded our inbox for almost a year with emails saying he wanted to see it happen, and that if we didn't do it, he would.

Our goals were simple: an LS small block, a manual transmission, and no discernible difference from afar. The questions that followed were not simple. Where will that motor hide? How will we cool it and feed it air? Can you cut a Tesla in half without the chassis failing? Can you still run Tesla's computer without the Elon Duracells? Where does the new fuel cell go? Will the aluminium chassis handle the flex from the heat and torque, or reject the V-8 transplant? Will

Elon Musk take us to court? Can they still track the car if we think we disabled the LTE/WiFi?

In December 2019, we pulled the car out of storage and stripped the interior and computer to begin measuring everything to see where a new drivetrain might fit. The first order of business was to remove the air-conditioning unit and frunk. Then we could determine how much room we had for a motor and test the space with foam engine mock-ups.

Instead of actually buying a crate motor from GM, we spent many a night eBaying for potential donors to keep costs down. Eventually we landed on a 426-horsepower 6.2 L Chevy LS3 motor from a wrecked 2011 Camaro SS. To everyone's surprise, it fitted like a glove in the Model S frunk-turned-engine-bay, and the bonnet latched in place on the first try.

While that V-8 hogs all the attention, the crux of the build was actually creating a tunnel for the transmission and driveshaft down the middle of a car that comes with a flat underside. The flat floor is most obvious when you notice the lack of a centre console hump in early Teslas. This was a specific request by Musk, a subtle flex highlighting the lack of a certain bulge most every other car on the road needed.

Once the 545 kg battery pack and its 16 corroded modules were dropped, the real fun began. We brought the shell to Joshua's garage to go under the knife. Technically, Joshua was a stranger we'd only met on the internet. But he said he had significant welding experience and really enjoyed our YouTube channel. Seemed legit enough that we didn't worry about being murdered in an alley. On our first visit to his garage, we saw walls covered with the body panels of Nascar vehicles Joshua had built. We knew then that we'd make this daydream a reality.

The Tesla body is mostly aluminium to offset the batteries' weight. But aluminium is softer than the typical carbon steel used for auto frames, and we needed to cut a seam down 70 per cent of the length of the car to make way for a driveshaft. This posed the challenge of maintaining the structural integrity of an area that was also never designed to absorb the heat and torque of an LS motor. So to avoid creating a frame that wanted to fold in half, Joshua added a rib cage of bracings to the underside.

Our team fabricated and fitted motor and transmission mounts and had a custom rear axle built. Once the drivetrain lined up, we saw one last major complication: How would we install a shifter that didn't smash your fist into that 17-inch touchscreen? Our intention was to keep the vehicle looking as close to stock as

'WE NEEDED TO CUT A SEAM DOWN 70 PER CENT OF THE LENGTH OF THE CAR TO MAKE WAY FOR A DRIVESHAFT.'

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possible on all fronts, so that at least from a glance, if you didn't hear the thunderous babble of a V-8 idling, you would assume it was a regular Tesla. The touchscreen had to keep its spot, and if we couldn't hide the shifter, at the very least it needed to look good. Originally we thought it funny to have a huge gated shifter with a Tesla battery cell as the grip, but ultimately we installed a short throw shifter to keep a safe distance from the screen.

Once this was in place, we felt confident not just that our build was in the home straight but that we finally had a car that could mark our arrival at SEMA. Four months remained until the show. Surely that was enough time.

While we were piecing together the drivetrain in one garage, Chad Hrencecin and Bryan Maynard from the Electrified Garage had the shell in another. They pulled out nearly 1 650 m of wiring, keeping only what was needed to power the normal features of the car from its touchscreen, and wired up a new fuse block in the cubbyhole.

Bryan also fabricated our heat shield, a 10 mm aluminium face with a ⅛-inch composite glass-fibre core. Despite pulling the engine in and out a dozen times to perfect the fit, we needed to finish the wiring when it was time for the shielding to go in. So Bryan had to cut and mould the shielding around the motor by hand while it was in place.

An LS3 doesn't move on the power of our hopes and dreams, so we needed a fuel cell. Fortunately, the Model S's boot has a sub-level void that can also be used for a seven-seater configuration to let two kids in reverse jump seats dangle their feet into the rear hatch. Sorry, kiddos, we filled the space with a 53 litre fuel tank and chased a line to the filler cap into the Tesla's rear tail light, where the charge port used to be.

Then there was the problem of how to cool the motor. Another flex in this Tesla's designs are the solid, no-grille front ends. It's more aerodynamic and signifies that they don't need air flowing to a motor. We wanted to keep that appearance, but our motor very much needed air. EVs do, however, have giant batteries that need to be cooled, lest they start a fire. Our Tesla has an air duct for the batteries' radiator tucked into the bumper, so we kept the original vents and rerouted the air to the engine and its radiator.

We now had something that looked like a functioning vehicle. The drivetrain was installed, and the body had been 'upgraded' for it. But with a month to go, there was still a lot to do before we could arrive at SEMA with a motor that made noise. Stock Teslas are largely silent; ours had to be different.

'THE SOUND WAS SNAPPY, THROATY, AND DOWNRIGHT MEAN.'

PHOTOGRAPHY: COURTESY STEVEN SALOWSKY (THIS PAGE)

Stopping for a quick break and photo op at Zion National Park en route to SEMA in Las Vegas.

Taking our showstopper for a drive near Plum Island, Massachusetts.

We had to put together an exhaust system, wire up a Haltech tuner to communicate with the motor, reupholster the interior for the transmission hump, and add structural bracing above the LS3. All the while we were waiting for at least 24 more parts to arrive, most being fitments for the fuel lines – non-negotiable for firing up the motor. Great. We could alter or fabricate our way out of most problems, but not this one.

Normally we're a chipper group of people, but two weeks out, our garage felt like a funeral home. We were eating meals in there, napping on-site in a Mercedes Sprinter van conversion, and showers? Meh, no one was coming near us anyway. The lack of sleep started to make us feel numb inside, but we could see the finish line again. Then we got a call that the fitments were delayed. There was no way our Tesla could drive on to the trailer under its own power for the trip to Vegas.

There was one last option. We didn't like it, but it gave us a shot. We could buy three days by driving the Tesla ourselves from the Electrified Garage in New Hampshire to SEMA. Truckers are required by law to stop every eight hours, but as a group of madmen we could drive around the clock and then finish it with Geddy Getz, a local LS specialist.

After 2 733 mind-bending miles (seriously, check out how weird it gets on our YouTube channel), we pulled into Geddy's driveway on Monday morning at 8 am. We had until 5 pm to deliver the car 20 minutes down the road to the SEMA floor. Taking our box of fitments, Geddy tuned the motor so that it didn't run too lean and sound like a clangourous mess of sputters and backfires, or too rich that it bogged itself down and smelt like a BP tanker spill. Either option would be as embarrassing as pushing the car to its booth. We had precious few hours to find the balance, and then … the cylinders started to align like the planets to an astrologer. The sound was snappy, throaty, and downright mean.

We drove into SEMA with two hours to spare. It was time to scare and confuse people with something they'd never seen or heard before. Our work isn't conventional, but you have to respect it – we received praise and admiration from a lot of our industry heroes that week.

It's funny, we've been looking at the Tesla T on bonnets of ever-so-quiet cars for the better part of a decade. But when our eyes drift to the side exhaust on our Model S, they begin to moisten from the inky smoke of 376 cubic inches ready to lay down now-444 ponies. We're brought back to the thing that made us love automobiles in the first place: the thunderous sound of power. **PM**

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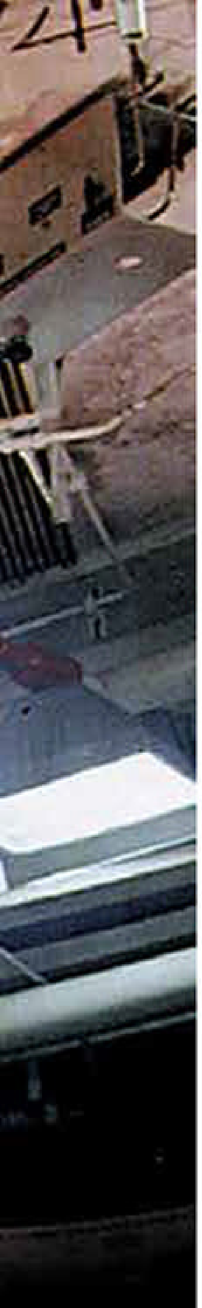
HOLLY-MANDARICH-UVYOFX3V0LS-UNSPLASH

An RS-25 engine performing a hot-fire test.



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The space shuttle's main engine was mothballed with the programme in 2011. Now NASA believes it's the future of interplanetary travel.

CAN A RETIRED ROCKET ENGINE TAKE US TO MARS?

BY JOE PAPPALARDO

PHOTOGRAPHY: PREVIOUS PAGE, COURTESY NASA; THIS PAGE, COURTESY: NASA

THE HEART OF NASA'S SPACE LAUNCH SYSTEM ARRIVED AT KENNEDY SPACE CENTER LAST APRIL AS THE AGENCY'S FIRST HUMAN-RATED DEEP SPACE ROCKET IN 50 YEARS.

» The 65 m core stage rocket, along with a pair of solid rocket boosters, and the Orion crew module largely make up the Space Launch System (SLS), which NASA is counting on for its Artemis programme's 2026 return to the Moon – a feat the agency last accomplished with Apollo 17 in 1972.

Despite the decades between manned lunar launches, the SLS relies on a workhorse from the shuttle programme. Mounted at the bottom of the core stage are four RS-25 engines – formerly called the Space Shuttle Main Engine (SSME) – supplied by Aerojet Rocketdyne. Originally designed in the 1970s, the engines are seasoned, upgraded veterans, with 25 previous space shuttle flights among them. Among the four engines mounted to the SLS are numbers 2045 and 2060, both used on 8 July 2011 to launch the shuttle's final mission, STS-135.

Doug Bradley was at Kennedy Space Center during that launch, working as a chief engineer for Rocketdyne. 'I've been to many flights, but it was different for 135,' Bradley says. 'It was electric. It was a very emotional flight.'

The retirement of the space shuttle left Rocketdyne with a backlog of 16 engines, which the company mothballed. It was sad, says Bradley, to see them decommissioned when they could have flown dozens more missions.

Now with the title of Deputy Program Manager at Aerojet Rocketdyne, Bradley is overseeing the rebirth of the SSME engine. (A 2013 merger with Aerojet led to the company's current name.) And it's quite a comeback: SLS is the custom-built, off-planet ride for NASA's Artemis campaign to return humans to the lunar surface and later to land people on Mars. That puts the SSME, originally created with slide rules and paper, at the foundation of 21st-century human exploration.

'It's very gratifying to see those engines resurrected,' Bradley says. 'And what's better than going to the Moon and Mars?'

* * *

ROCKETDYNE BEGAN PRODUCTION OF THE SSME on 31 March 1972, but it'd be another five years before Bradley would come on board. An engineering graduate fresh from California Polytechnic State University in San Luis Obispo, Bradley got a tip from a neighbour and applied at Rocketdyne to work on the shuttle programme.

'I was old-school. Every design you were getting down on a physical drawing board with pens or pencils,' Bradley says. 'They started hot-fire testing engines in 1975, but in '77 we were still burning up a fair amount of them. I was in turbomachinery and we were taking the brunt of some of the damage, so it was very exciting.'

Four turbopumps are at the fiery heart of the engine's design. These spinning, whirling fans create the extreme pressure that carefully shoots liquid hydrogen (LH2) and liquid oxygen (LOX) to the main combustion chamber. These machines operate in brutal conditions, with heat as high as 3 300°C inside the chamber – hot enough to melt an iron bar into a puddle. But it's the temperature swings that introduce especially dangerous stress to the engine's delicately machined innards.

'Just on the turbopumps alone, you've got a couple of thousand degrees gradient from one end of it to the other,' Bradley says. 'The combustion chamber is even worse. They're at thousands of degrees with (physical) tolerances of fractions of inches.'

Making central air conditioning for the main combustion chamber required some novel thinking. In the early 1970s, Rocketdyne researchers created a new copper-zirconium alloy called NARloy-Z expressly for use on the engine. The new material could withstand pressure and temperatures that threatened to deform the tiny channels that deliver superchilled liquid hydrogen through the main combustion chamber's lining to keep it from burning up.

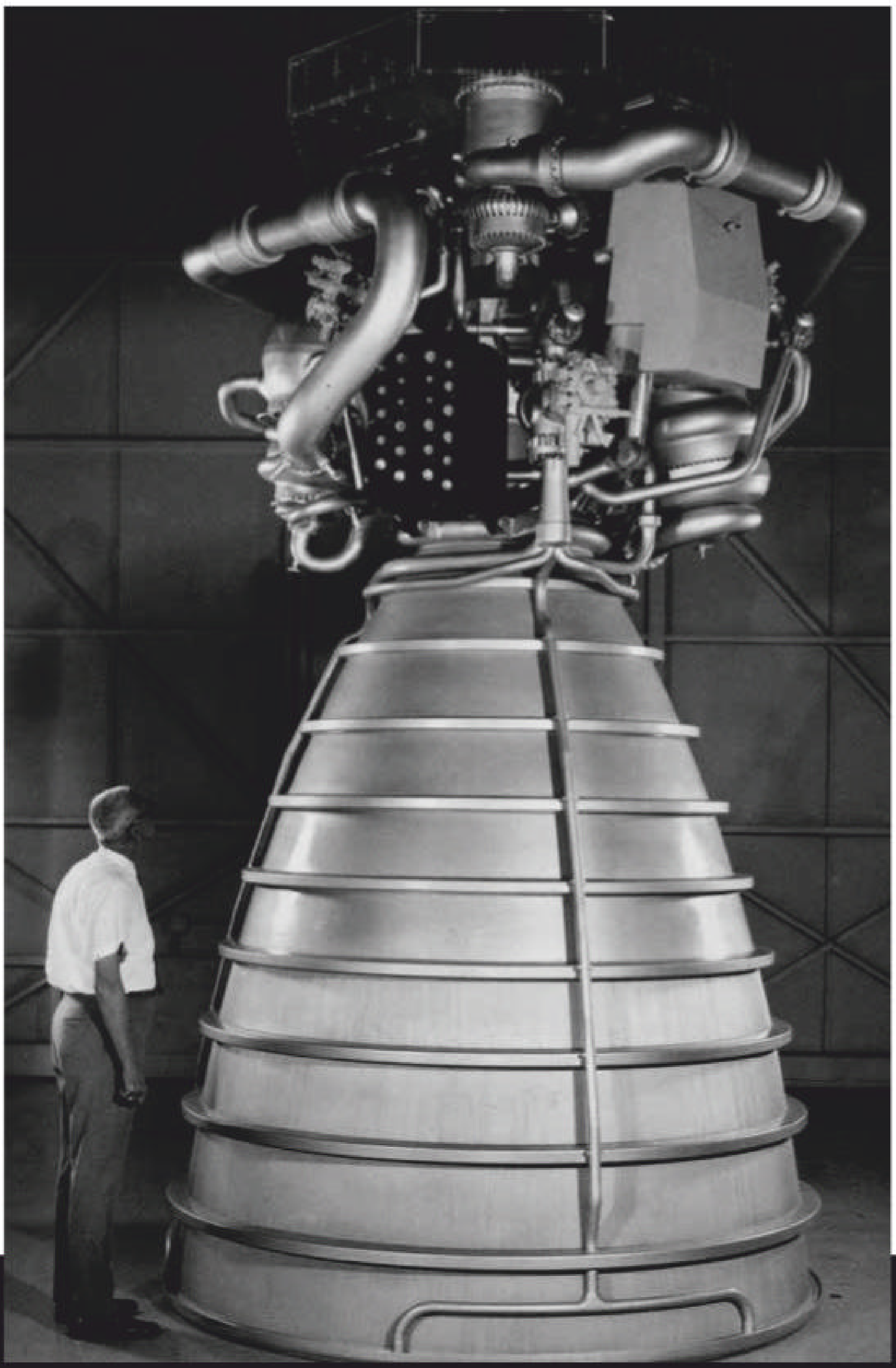
The SSME was also subject to years of testing conducted in an era before computer simulations. NASA dictated that the engines endure at least 65 000 seconds of flame and smoke on stands before making the first flight, even though the engine works for just 510 seconds during a mission. The trials included challenging the SSME to perform at power levels greater than the mission required. Decades later, when NASA was evaluating SLS engines, that extra thrust would prove invaluable.

The space shuttle launched on 12 April 1981, becoming the world's first reusable crewed spacecraft, and SSME the first reusable space rocket engine. When the orbiter landed, its SSMEs were removed, inspected, and refurbished before being readied for another mission.

'I call these my children because I've lived with all these engines from the day they were born, when they were tested, when they were flown,' says Bill Muddle, Aerojet Rocketdyne's RS-25 field integration engineer, who also worked on the shuttle programme. 'I got to touch and be part of all of those motors through their history for 125 flights.'

It turns out that the reusable engines, built to the same standards, developed what engineers call 'personalities' based on their performance and maintenance demands. It's a phenomenon seen in aeroplane hangars and shipyards – places where hardware is reused and the maintainers get to know it during a service life.

Left: Smoke from a hot-fire test. **Below:** An engine mock-up from 1973, eight years before its first flight.



PHOTOGRAPHY: GETTY IMAGES

And Muddle sees the existing stable of RS-25s in a similar, more personal way.

'I've got 16 unique children,' he remarks. 'I love them all to death, but they all have their idiosyncrasies.'

As the shuttle missions changed, the engine was asked to run at higher levels, up to 104.5 per cent of its rated power, mostly to handle greater weight for the International Space Station construction.

'They asked it to run at those high pressures and temperatures, and it came back every single time,' Muddle says. 'When you started that engine to put astronauts into space, it did.'

When the shuttle retired in 2011, so did the SSME, it seemed.

* * *

IN 2015, NASA PREPARED TO ANNOUNCE ITS choice of engines that would be used in its new Space Launch System. With a 30-year track record and more than 1 million seconds of total ground test and flight firing time, the venerable engine's history became a selling point, especially in a traditionally risk-averse NASA programme. SLS will be the largest operational launch system ever built, and efficient engines get more benefits as rockets scale up, which was good news for the SSME's bid.

'We measure efficiency in specific impulse (ISP), like fuel consumption figures for a rocket. Our ISP gets 452 seconds, which is very, very hot. For other rockets, that will be in the 300s,' Bradley says. 'The more efficient you are, the less propellant you have to lift. Efficiency means, in reality, cargo.' That's crucial, he added, for the Artemis programme, which aims to establish a sustainable human presence on the Moon and make crewed missions to Mars.

In November 2015, NASA awarded Aerojet Rocketdyne $1.16 billion to adapt the 16 mothballed SSMEs to the new launch system and restart the production line for six new engines, now renamed the RS-25. 'You hear that decision, you celebrate for 10 minutes, and then you get to work,' says Bradley. 'It's a different vehicle, so we've got a lot to do. The rocket's taller, so the pressure coming into the engines is higher when it's started.'

The space shuttles used three SSMEs, but the behemoth SLS demands four engines, which further changes the operating environment. There isn't much room to spare under the megarocket, especially given that people need room to work on them. 'There's only eight inches between the wall of that vehicle and the edge of the engine,' Muddle says. 'And I've got to put a technician in there that has to torque something.'

The nearby flames from the motors of 17-storey solid rocket boosters, one affixed to each side of the core stage, also now pose a threat. 'In the shuttle programme, our engines were 6 or 10 m higher than the boosters,' Bradley says. 'On this rocket, we're adjacent to them, and those are big, powerful beasts.' Extra thermal shielding now protects the four core engines from the two boosters.

During initial Artemis SLS launches, RS-25 engines will have to run at the maximum the SSMEs were designed for, 109 per cent of the space shuttle's main engine power.

Starting with the fifth Artemis mission, the engines will be called on to reach 111 per cent of the shuttle-era output. 'Without any redesign per se, we can go ahead and throttle up a little bit higher. And we think we can go higher than that,' Bradley says.

The enduring use of this engine speaks to the strength of its original design, says Muddle. 'You ask something to throttle up to 111 per cent, 114 per cent, and then also be able to throttle down to 65 per cent; that's a huge range to ask a rocket engine to do.'

NASA doubled down on the RS-25 in May 2020, when it awarded Aerojet Rocketdyne $1.79 billion to produce 18 more engines, on top of the six already on order. The combined price of this new RS-25 contract and the earlier one – resulting in a tab of possibly more than $100 million for each single-use SLS engine – has raised critical eyebrows.

After all, each SSME cost an estimated $40 million. And in 2018, United Launch Alliance paid Blue Origin an estimated $14–$16 million per pair of its new BE-4 engines to use for ULA's Vulcan Centaur rocket. The BE-4 produces similar thrust to the RS-25, but Blue Origin has not released its ISP.

Aerojet says a per-engine calculation is unfair, since the contract's fee includes new hardware for additional testing, as well as investments in manufacturing that will generate overall savings. That's still a lot of money for engines that will only be used once before being discarded into the ocean.

Three SSMEs sit prominently on the back of the *Atlantis* space shuttle, pictured here on its final mission in 2011.

PHOTOGRPHY: NASA VIA GETTY IMAGES

The SLS's 65 m rocket core stage, en route for testing at NASA's Stennis Space Center.

PHOTOGRPHY: COURTESY NASA

Dealing with an expendable launch system is new for the SSME veterans at Aerojet Rocketdyne, where the primary design and manufacturing ethos had changed from reuse to cost reduction. Company facilities in California and Florida are creating legacy engine components using 21st-century manufacturing techniques, such as laser printing, to reduce the time needed to make and quality check engines. 'The main things we're working on right now are retaining reliability and making it less expensive,' Bradley says.

The new RS-25s will only be fired during one test and one launch, so the engines won't have the chance to develop those personalities that come from contact with maintainers.

The engine's return on a one-and-done rocket makes for an emotional, bittersweet return. 'I was sad to see my children go, but they're going off to college now,' Muddle says.

* * *

ON 28 JANUARY 2021, AN RS-25 DEVELOPMENTAL engine fired for a full duration, the entire 500 seconds it takes to vault Orion into orbit. Bradley went to Stennis Spaceflight Center in Mississippi to work the test – familiar ground for the now high-ranking executive engineer.

The visit triggered memories of the first rocket engine test Bradley observed as a fresh Aerojet hire at the same location. He watched from the roof of a building just half a kilometre away from where the engine roared to life, assaulting his ears and spreading shock waves through his chest. 'My thought at that time as a young engineer was: "How does that thing stay together?"' Bradley says.

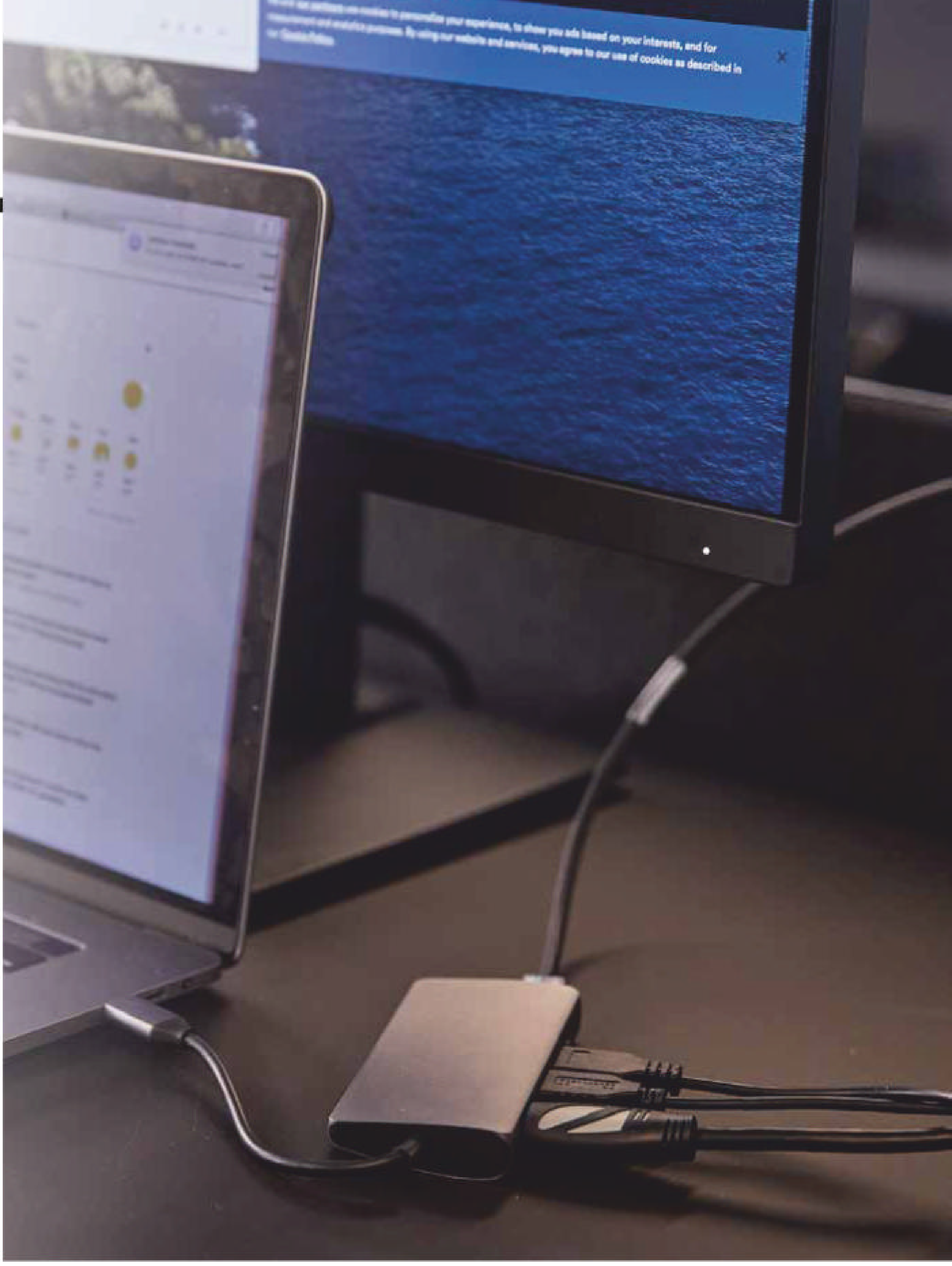
Watching the RS-25 flare to life in January 2021, thundering well past the original limits of its design, reignited those memories. 'I've got to admit that during the last single engine test, I had the same thought,' he says. 'I've been in this business for a long time, but the amount of power that we're harnessing – I just never take it for granted.'

The SLS is scheduled to make its maiden voyage very soon, carrying an Orion capsule with an instrumented mannequin in the seat where astronauts will one day sit, and Bradley plans to see his old friend fly again.

'I'll probably have a job to do,' Bradley says. 'But I'm hoping I can sneak outside three minutes before the launch and watch it with my eyeballs.' **PM**

HOW TO USE IT

/ BY HUNTER FENOLLOL /



Unlock your devices' full potential with a USB-C hub

AS NEW TECH SHRINKS EACH YEAR, essential ports such as USB-A, HDMI, and ethernet are being replaced by the slimmer USB-C. A hub (often referred to as a dongle) is a small, port-laden gadget that plugs into a single USB-C slot on devices such as laptops, transmitting advanced data and power signals to stand in for those disappearing inputs and restore functionality.

Befitting a tool that connects many others, these hubs are versatile, sometimes in ways that aren't always apparent. Through them, many electronics you already own can connect to peripherals and displays. With some experimenting, you can turn a streaming stick, gaming console, or phone into fully functioning computers.

SWITCH BETWEEN A LAPTOP AND A DESKTOP

→ You probably know how to use a USB-C hub to add external devices such as a hard drive and mouse to your laptop. You can take your USB-C hub a step further to create a full workstation, complete with a dual-monitor setup. With double the screen space, you can juggle multiple open app windows. Typists who prefer the feel of mechanical keys can connect their favourite keyboard to the hub, while those who crave precise pointer control can plug in a mouse. We recommend that your USB-C hub has an HDMI port with at least 60 watts of passthrough charging power to provide enough juice to your laptop and each connected accessory. If you have a lot of devices or a power-hungry laptop like a MacBook Pro, look for a hub with a minimum of 100 watts for stable performance. Say you're just connecting to a mouse and a keyboard, plus the occasional webcam or microphone; five ports should do.

STEP 1 Plug your laptop's USB-C charger into a wall outlet and connect the USB-C end into the hub's passthrough power delivery port (indicated by an image of a plug or the letters PD).

STEP 2 Neatly load up your USB-C hub with a mouse and keyboard of your choice in any lower-bandwidth USB 2.0 slots. (USB 3.0 is preferable for power-hungry devices such as webcams, microphones, and hard drives, as it provides better performance.)

STEP 3 Attach an HDMI wire from an external display to the HDMI port on your USB-C hub.

STEP 4 Hook up the USB-C hub to your laptop to start charging and connect it to every device you have plugged in. When done correctly, you should see your laptop's background image spring to life on your second monitor and be able to take the reins via the mouse and keyboard you hooked up. And since everything plugs into your hub and attaches to your laptop through that, all you have to do when you need to move around the office or head home for the day is unplug the single wire connecting the dongle to your laptop. This gives you the wireless freedom and portability of a laptop but makes it easy to hook up to the slew of devices on your desk without the need to reattach each individual one.

TURN YOUR STREAMING DEVICE INTO A LIVING-ROOM PC

→ A Chromecast with Google TV, with the help of a USB-C hub, can function as a full-fledged living-room computer with your TV as the monitor. Surf the web, share USB or SD stored media with a group, or video chat with friends and family.

STEP 1 Using a 60-watt power brick (we recommend Anker's PIQ) to ensure there's surplus power for not only your Chromecast but attached devices too, plug the USB-C wire into the USB-C hub's PD port.
STEP 2 Load up your hub with a wireless keyboard receiver, webcam, and SD or USB card storage. Plug the USB-C hub into the Chromecast device.
STEP 3 Navigate to the Play Store using your Chromecast to download a browser such as Puffin, which you can use to surf the web on your TV screen.
STEP 4 View your media using an app such as VLC Media Player. After opening the app, navigate to your connected device, and select the media file you want to open up.
STEP 5 Download Google Duo, and connect a webcam to create a video-capture source. Give your contacts a call to video chat over Google Duo.
STEP 6 (optional): Connect an ethernet cable to your USB-C hub for a hardwired connection to eliminate stream buffering.

TURN YOUR TABLET INTO A MOBILE CONTENT-CREATION STATION

→ Despite manufacturers' best efforts, tablets remain the overlooked middle child between phones and computers. There's a common misconception that they aren't serious production machines, but linking them up with a USB-C hub can make them legitimate alternatives to laptops. Attach a powered USB microphone through a USB-C hub to facilitate quality podcasting or livestreaming. Or connect a keyboard to write out scripts or a mouse to work on designing visual social media posts in content-editing suites.

STEP 1 Plug in your tablet's wall adapter and connect the USB-C charger into the hub's passthrough port.
STEP 2 Load up your USB-C hub with production equipment such as a USB mic, keyboard, or control deck.
STEP 3 Open up a recording app to monitor your audio input source, and ensure it matches the name of your attached accessory.
STEP 4 Connect a mouse and keyboard for design or text work.
STEP 5 Launch into a media-editing suite to start recording. If you're into live broadcasts, crack open your platform of choice and start rolling.
STEP 6 If you would like to share your work with a group or simply view it on a full-size screen, attach an HDMI cable to your USB-C hub. The screen will pop up on your external display.

PHOTOGRAPHY: LAKOTA GAMBILL

TURN YOUR PHONE INTO A GAMING CONSOLE

→ You can take your favourite mobile game to a bigger screen by connecting your phone's USB-C port to a hub equipped with an HDMI output. Plugging the other end of the HDMI wire into a TV or computer monitor presents your app in a widescreen for more details and action. Unlike when using wireless protocols to cast your display, there's virtually no lag, resulting in smooth competitive play. If your USB-C hub has an ethernet jack, you'll even be able to hardwire a rock-solid connection and avoid the network interruptions that can happen over WiFi. Add a wireless controller to this set-up and you'll get a console-like performance and experience from your mobile gaming device.

STEP 1 Connect your phone's charger to a wall outlet and the USB-C end into the PD port.
STEP 2 Plug your TV or monitor's HDMI cord into the hub and set your display to the appropriate input.
STEP 3 Connect your phone to the other USB-C port on your hub to charge.
STEP 4 View your phone on the TV and confirm your desired resolution.
STEP 5 Pair a Bluetooth controller (such as your Xbox or PlayStation's) to your phone.
STEP 6 Load your favourite mobile game and play on the bigger screen. **PM**

PRACTICAL KNOWLEDGE

↓ GRINDERS

/ BY HUNTER FENOLLO /

Making the most out of your grinder

CAUTION
KALAMAZOO INDUSTRIES INC KALAMAZOO MI
CAUTION
- WARNING -
DO NOT INTERMIX SANDING OF METAL - WOOD - PLASTIC
DANGER OF FIRE OR EXPLOSION
KEEP MACHINE CLEAN
ALWAYS WEAR SAFETY GLASSES
KEEP TABLE LESS THAN 1/8" FROM BELT

Grinding the end of steel bar stock with the work rest set at 90° to the platen.

THE HUMBLE BENCH GRINDER IS A STAPLE of the handyworker's home shop, largely due to its versatility. But, while you can employ one to remove metal from just about anything, the traditional kind may not provide the precision you need for every grinding operation. Here, we shed light on the best ways to use the different types of grinders, gleaned from our testing.

Bench grinder

→ What could be simpler than using a bench grinder? Step up to the machine, turn it on, and press an offensive bit of metal into the spinning, abrasive wheel. Right? Well, yes, and no. There are some things to keep in mind to grind both successfully and safely.

Heat is your enemy. It builds up very quickly, can damage metals, and makes things too hot to hold. Pressing hard to remove material in one spot will generate a lot of it. Keep your workpiece moving and make use of the full width of the grinding stone. Keep a cup or tray of water on hand to cool metal parts when you feel them getting hot.

Another reason to keep whatever you're grinding moving is to prolong the life of the abrasive wheel. Working in one spot on the wheel will cut a groove in it or round off an edge; it's better to spread the wear more evenly. And if being able to grind something square is important, keeping the face of the wheel flat will make it easier.

Wet/dry sharpener

→ Sharpening knives and tools seems to mystify people, and there are a lot of gadgets available intended to make the process simple. However, using a basic water-cooled sharpener is an easy and time-tested method for a wide variety of blades, from axes to pocketknives. And, while the individual steps might differ from one item to another, there are some best practices to follow for all of them.

- Figure out the correct angle at which to sharpen the tool or knife (generally 17° to 20° for kitchen knives and 20° to 30° for chisels and pocketknives). Set up the jig or tool holder so it's square to the sharpening wheel and the tool contacts the wheel at the desired angle.
- Fill the reservoir with water and rotate the wheel, letting the stone absorb the water. Keep topping up the reservoir until the stone has absorbed all it can and the water level stops dropping.
- Make sure the wheel is turning in the correct direction for whatever you're sharpening. For knives, the wheel should turn away from the edge – sharpening towards it removes more material faster, and it's far too easy to grind

away too much. Grind chisels, hand-plane blades, and axes with the wheel turning towards the edge. Since these are thicker and have a lot more material to work with, they generally can afford removing much more metal to achieve a new, fresh edge.

- Keep the tool moving, using the entire surface of the stone. This ensures you're removing material evenly from the tool and keeps the wear on the stone flat and uniform.
- Hone off the burr or wire edge that is created during sharpening, by hand, with a couple of passes on a whetstone.
- Swap in a leather stropping wheel to finish the edge and make it razor-sharp. The leather is treated with machine oil to keep it soft, and you should apply a small amount of abrasive stropping paste to the wheel, too. Do this with the wheel turning away from you and from the sharpened blade – it will polish any remaining imperfections.

Belt grinder

→ Belt grinders excel where precision is required, with the ability to create surfaces that are flat, square, or bevelled at an angle.

For many grinding tasks in fabrication and repair, you'll want to set the work rest to 90°. Use a square to set it perpendicular to the belt where it travels over the platen – that's the hard surface that supports the belt. If you need another angle, you can set it using a sliding T-bevel.

As is the case with most grinding operations, keep the workpiece moving to prevent it from getting too hot, and use the full surface of the abrasive belt. Belt grinders don't create as much heat as their wheeled counterparts, but you should still keep a cup or tray of water on hand to cool the workpiece.

Often work rests can come off so you can grind long, flat edges or surfaces, and the head can rotate to orientate the platen horizontally.

DEALING WITH DUST

Grinding is messy – grit flies everywhere. While it may be tempting to use a traditional shop dust-collection system, don't. Particles of metal coming off grinding wheels are hot and could ignite fine, dry sawdust in a dust collector, causing a fire. There are dust-collection systems specifically for grinding, but they're usually geared towards commercial use, quite expensive, and not practical in a home. Try these strategies to deal with the grit flying around in your shop.

1. Wear an N95 mask or respirator to prevent inhalation of dust and grit (along with eye protection or a face shield).

2. Bolt your grinder to a pedestal or small stand so you can orientate it away from other work surfaces or in an area of the shop where dust and grit won't harm anything.

3. When possible, position grinding wheels over the end of a bench, so debris can fall to the floor.

4. If a grinder is bolted to your workbench, build an open metal box behind it to prevent grit and dust from covering everything else on the bench.

5. For shops in the garage, pull vehicles out on to the driveway before beginning work. This will protect painted and polished finishes, as well as glass, from potential scratches.

6. Whenever possible, use a shop vacuum to clean up debris immediately after grinding sessions.

7. If you have a significant amount of grinding to do, keep drop cloths or old bedsheets around to cover anything else in the shop you want to protect.

GENERAL GRINDING SAFETY

EYE PROTECTION

Use it. Take it from someone who had a tiny bit of hot metal fuse to their eye that needed removing. Aside from that not being fun, the risk of losing sight is just not worth the time it takes to don eye protection. While there are all kinds of fancy types, an ordinary set of goggles is all you need.

GLOVES

They seem like a good idea, but grinding wheels – as well as wire wheels found on many grinders – can grab gloves, pulling them, and hands, into the machine. So skip them.

LONG HAIR AND LOOSE CLOTHING

Just like gloves, anything long and loose – hair and clothing, for example – can get caught and pull you into the machine. Tie your hair back, and avoid baggy clothes around the grinder.

WORK RESTS

Use these platforms whenever possible to steady whatever you're grinding and manoeuvre it on the wheel. When that isn't practical, grind on the lower half of the wheel; that way, if the workpiece catches, it will be thrown down rather than towards you. **PM**

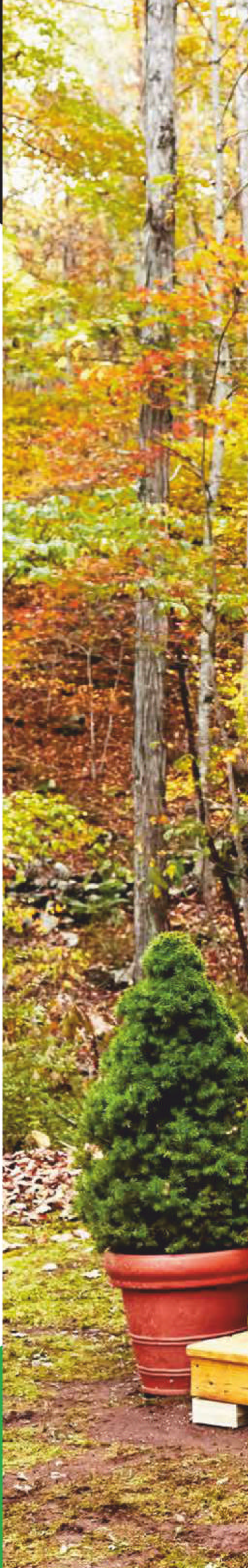
PHOTOGRAPHY: LAKOTA GAMBILL

HOW TO BUILD a BACKYARD GREENHOUSE

Step-by-step plans for making a plant-filled oasis

BY JOSEPH TRUINI

PHOTOGRAPHY BY HENRY HUNG



Many backyard gardeners start their plants indoors in late winter or early spring, before the weather is warm. But the best way to jump-start plants for spring gardening and also extend the growing season into winter is with a backyard greenhouse. Our design is a 1.8 m × 2.4 m (6 × 8 foot) structure, large enough to accommodate dozens of plants but compact enough to fit into the smallest garden. It's also easy to build, requiring only basic carpentry skills and easy-to-use tools. You can finish it over a couple of weekends.

The cost of the materials to build our greenhouse was about R20 000. That's higher than some preassembled greenhouses, but our materials are more reliable than any 'snap together' model; plus, this one is customisable. We include a potting bench, overhead plant hanger, and deck, but you can add or subtract features as needed. Whether you're an expert gardener or a rookie, our greenhouse will expand your gardening potential and diversify the kinds of plants you can grow at home.

SPECS AND MATERIALS

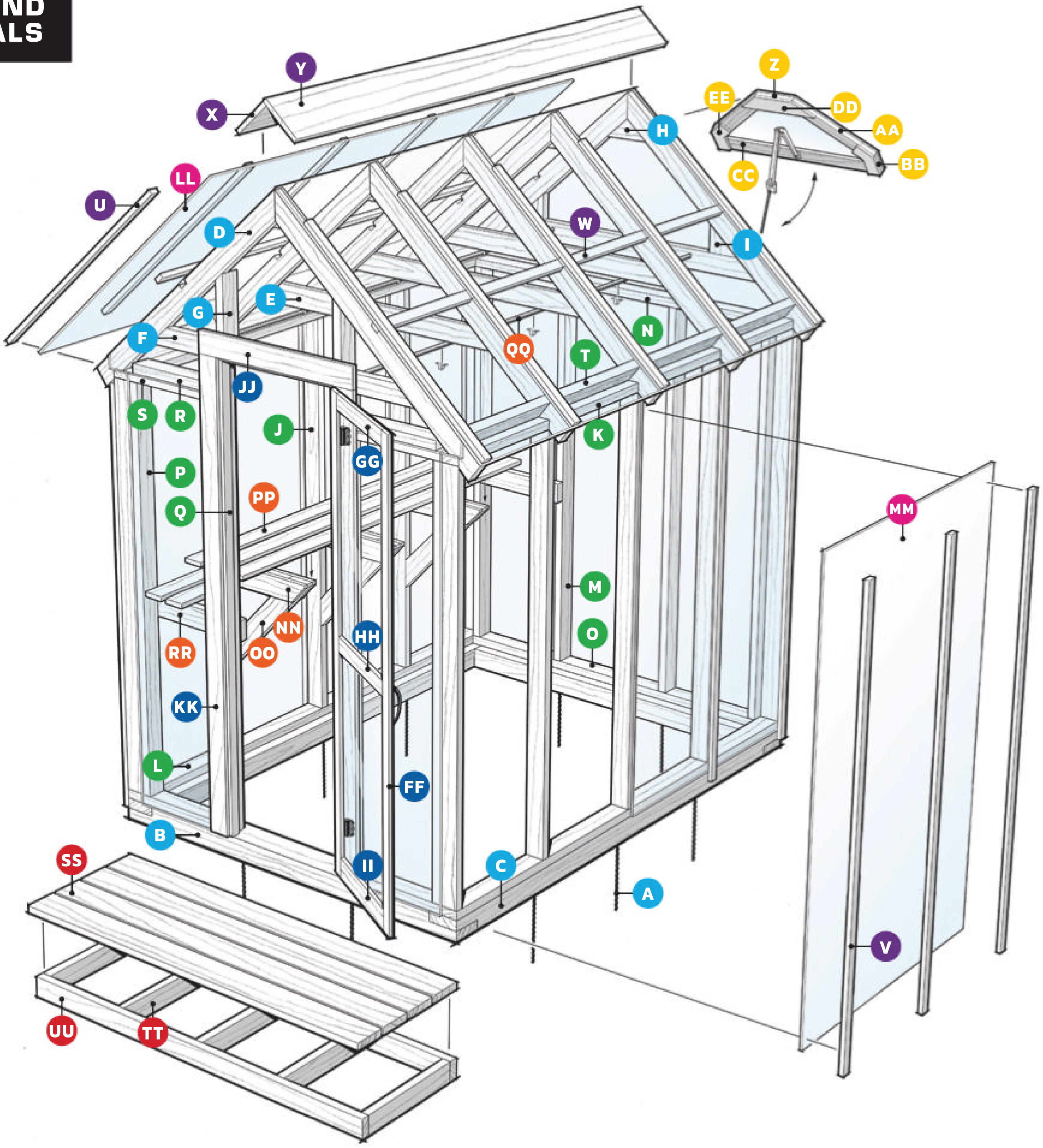


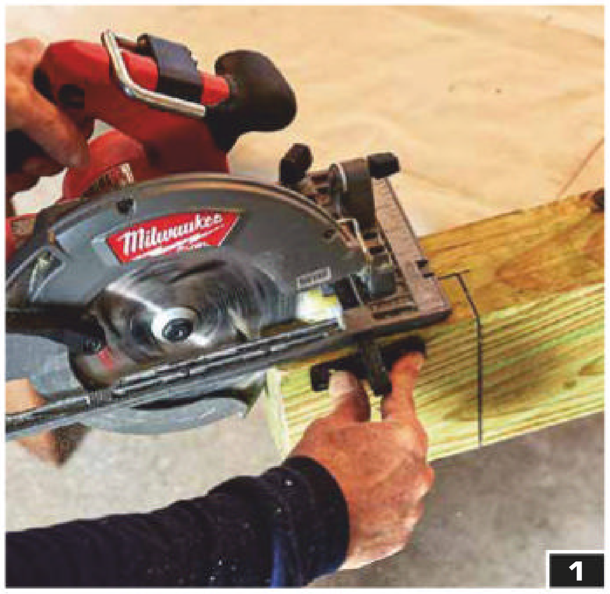
ILLUSTRATION: GEORGE RETSECK

Part	Qty	Size and description
A	10	12 × 460 mm reinforcing bar
B	2	89 × 140 × 1 830 mm timber-frame foundation
C	2	89 × 140 × 2 440 mm timber-frame foundation
D	10	38 × 89 × 1 335 mm rafter
E	3	19 × 89 × 1 525 mm intermediate truss collar tie
F	2	38 × 89 × 1425 mm gable-end truss collar tie
G	2	38 × 89 × 345 mm front truss vertical blocking
H	1	38 × 89 × 215 mm rear truss top block
I	2	38 × 89 × 180 mm rear truss side block
J	10	38 × 89 × 1 760 mm sidewall stud
K	2	38 × 89 × 2 440 mm sidewall top plate
L	2	38 × 89 × 2 440 mm sidewall sole plate
M	4	38 × 89 × 1 760 mm rear wall stud
N	1	38 × 89 × 1 650 mm rear top plate
O	1	38 × 89 × 1 650 mm rear sole plate
P	2	38 × 89 × 1 760 mm front wall stud
Q	2	38 × 89 × 1 925 mm front wall trimmer stud
R	2	38 × 89 × 450 mm front wall top plate
S	2	38 × 89 × 473 mm front wall top plate
T	8	38 × 89 × 585 mm eave blocking (Trim eave blocking to finished length on-site)
U	10	19 × 28 mm roof battens
V	10	19 × 28 mm sidewall battens
W	2	19 × 28 × 2 440 mm rafter strapping
X	1	19 × 184 × 2 515 mm ridge cap
Y	1	19 × 184 × 2 515 mm ridge cap
Z	1	19 × 64 × 210 mm vent frame top
AA	2	19 × 64 × 180 mm vent frame side
BB	2	19 × 64 × 105 mm vent frame end
CC	1	19 × 64 × 924 mm vent frame bottom
DD	1	84 × 406 mm vent top plywood gusset
EE	2	64 × 178 mm vent side plywood gusset
FF	2	19 × 64 × 1 950 mm door stile
GG	1	19 × 64 × 491 mm door head rail
HH	1	19 × 64 × 491 mm door mid rail
II	1	19 × 89 × 491 mm door bottom rail
JJ	1	19 × 89 × 813 mm door head casing
KK	2	19 × 89 × 1 956 mm door side casing
LL		Polycarbonate roof panel
MM		Polycarbonate sidewall panel
NN	6	19 × 89 × 540 mm potting bench support
OO	3	38 × 89 × 654 mm potting bench brace
PP	4	19 × 89 × 2 440 mm potting bench slat
QQ	1	13 mm-diameter × 2 388 mm conduit for hanging plants
RR	2	38 × 89 × 508 mm cleat
SS	4	22 × 144 × 1 830 mm decking
TT	5	38 × 89 × 520 mm deck floor joist
UU	2	38 × 89 × 1 830 mm deck band joist

CUT THE TIMBER FRAME FOUNDATION

Start by crosscutting two pressure-treated 89×140 mm timbers to 2 440 mm long, and two others to 1 830 mm long. Mark both ends of all four timbers for a 44 mm-deep × 140 mm-wide half-lap joint. Set the depth of cut on your circular saw to 44 mm, and make a shoulder cut across the timber precisely 140 mm from each end of the four 89×140 mm boards. Then set the saw to its maximum depth of cut and make the cheek cut in from the end of the timber **[1]**.

Flip the timber over and make another cheek cut into the opposite edge. To complete the half-lap joint, trim away the last bit of waste wood with a reciprocating saw or handsaw. Repeat to cut half-laps into both ends of all four 89×140 mm timbers. Lay out the 1 829 × 2 440 mm timber frame foundation, overlapping the half-lap joints at each corner. Measure the opposing diagonals to check that the foundation frame is square and make adjustments as needed; then secure each half-lap joint with two 90 mm-long structural screws **[2]**.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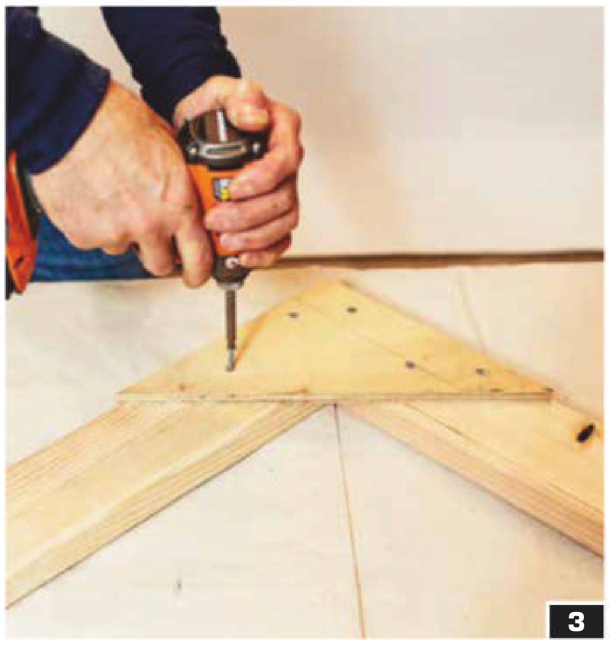
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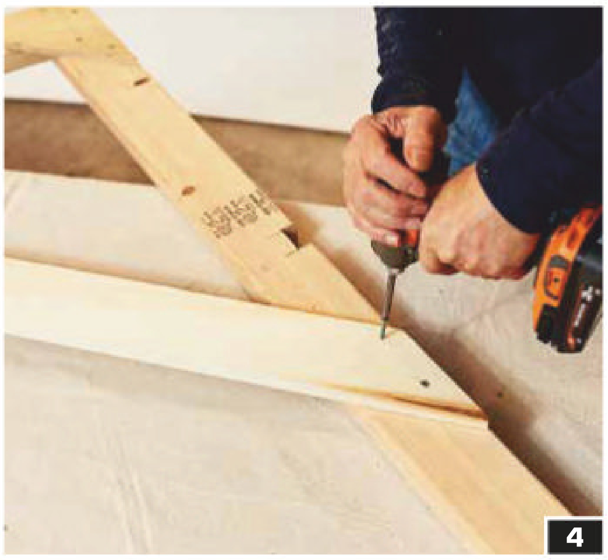
BUILD THE ROOF TRUSSES

In this build, you'll prefabricate the roof trusses that frame the greenhouse roof to simplify the framing process. Each truss is composed of two angled roof rafters and a horizontal collar tie. There are five trusses in all: front and rear gable-end trusses, and three intermediate trusses. Begin by cutting ten 38×89 mm rafters to 1 335 mm long. Mitre-cut the top end of each rafter to 40°; leave the bottom end square. Next, measure up 64 mm from the bottom of the rafters and cut a small notch known as a bird's-mouth cut. These notches allow the lower end of the rafters to sit flush on top of the sidewalls. (See the photos on page 88 for more information.)

Also, measure down 648 mm from the upper end of each rafter and cut a 19 mm-deep × 38 mm-wide notch into the top edge of each rafter. Cut the 19 mm-deep sides of the notches with a jigsaw, and then chop out the block of waste wood with a hammer and 38 mm-wide chisel. These notches will accept a 19×38 mm strap after you install the trusses. To assemble the trusses, butt together the 40°-mitred ends of two rafters. Then glue and screw a 12 mm plywood gusset plate over the joint between the rafters **[3]**. (We used yellow decking glue throughout this project.) Fasten the gussets with 32 mm decking screws. Repeat for the remaining four pairs of rafters.

For each of the three intermediate trusses, cut a 19×89 mm collar tie to 1 525 mm. Mitre-cut each end of the collar tie to 50°, then glue and screw it to the rafters with 40 mm decking screws **[4]**. For each of the two gable-end trusses, cut a 38×89 mm collar tie to 1 425 mm long; mitre-cut each end to 50°.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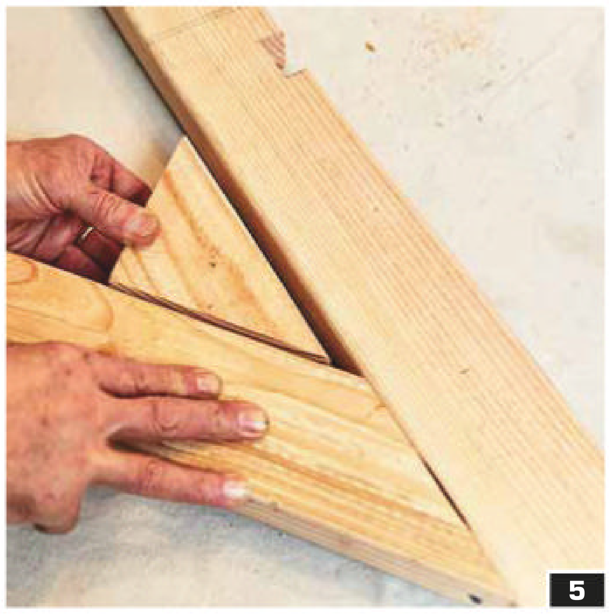
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Set each collar tie in between and flush with the rafters, then screw it in place with 50 mm decking screws.

To the rear gable-end truss, add three small triangular 38×89 mm blocks. Place one in each lower corner, between the rafter and collar tie [5], and one in the upper corner tucked beneath the gusset plate. The blocks create a rough opening for the operable air vent. To the front gable-end truss, install two 345 mm-long vertical 38×89 mm blocks. Mitre-cut the upper ends of the blocks to 40°, and notch the bottom ends to fit snugly over the 38×89 mm collar tie. These two blocks provide fastening support for the polycarbonate panels.

→ CUT AND ASSEMBLE THE AIR VENT FRAME

Make the frame for the air vent from six 19×64 mm boards. Cut the top 19×64 mm to 210 mm long, and the bottom 19×64 mm to 924 mm; square-cut both ends of each piece. Next, cut two short side parts to 105 mm long, mitring their upper ends to 40°. Lastly, cut the two angled parts to 435 mm long; mitre each end of both parts to 40°.

Assemble the air vent parts, then glue and screw a 12 mm plywood gusset plate across the top joints [6], and across the joint at each lower corner, with 32 mm decking screws.

→ MAKE THE GREENHOUSE DOOR

To make the 618 mm-wide × 1 950 mm-tall greenhouse door, start by cutting two 19×64 mm vertical stiles to 1 950 mm long. Next, cut the three horizontal rails to 491 mm long; cut the head rail and mid rail from a 19×64 mm board, and cut the bottom rail from a 19×89 mm board.

I joined the door frame parts using a plate joiner to cut slots for compressed-beech biscuit splines. Position the top edge of the mid rail 946 mm down from the head rail. After cutting corresponding slots in the parts, I applied glue to the slots, inserted the biscuits, and clamped the frame together [7]. If you don't have a plate joiner, glue and screw 12 mm plywood gussets across the joints with 32 mm decking screws. Let the glue cure overnight.

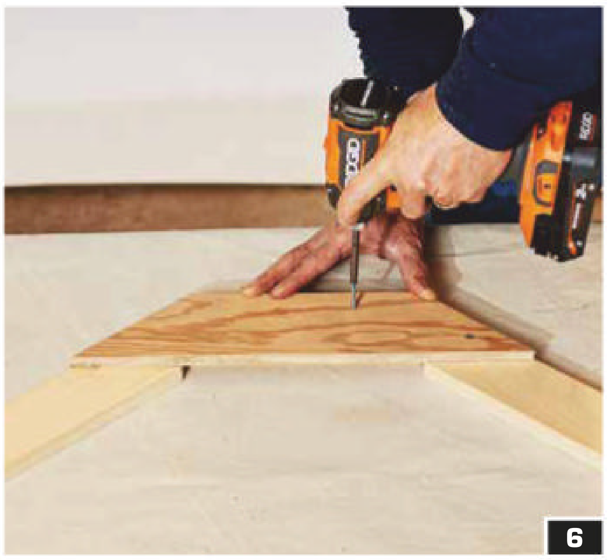
→ FRAME THE WALLS

All four walls of the greenhouse are framed with 38×89 mm boards. Cut the horizontal top plates and sole (bottom) plates for the two sidewalls to 2 438 mm long. For the rear wall, cut the top and sole plates to 1 650 mm. Next, cut five 38×89 mm studs for each sidewall, and four studs for the rear wall, to 1 658 mm. To assemble the walls, drive two 75 mm decking screws through the top and sole plates and into each wall stud [8].

To frame the front wall, which includes the doorway opening, you'll need ten 38×89 mm parts: Cut the sole plate to 1 650 mm and then cut two double-38×89 mm top plates. Each double top plate consists of a 473 mm-long 38×89 mm topped with a 450 mm-long 38×89 mm. Next, cut two wall studs to 1 658 mm long, and two trimmer studs to 1 925 mm. (The trimmer studs form the rough opening for the door.) Finally, cut a 705 mm-long 38×89 mm temporary header to span across the top of the trimmer studs. Screw the parts together with 75 mm decking screws. Once the wall is installed, remove the header. Use a paint pad to apply a coat of solid-colour stain to all surfaces of each part [9]. Allow the stain to dry overnight.

→ ATTACH THE POLY-CARBONATE PANELS

Doing this to the wall frames prior to erecting them will save you time and trouble. Begin by peeling off the clear protective film from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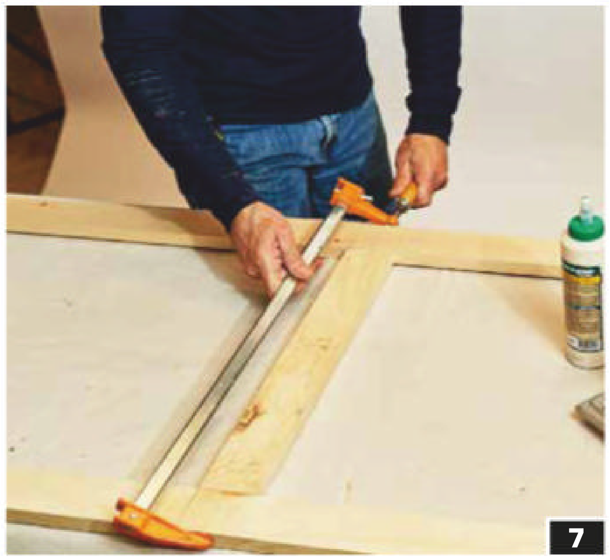
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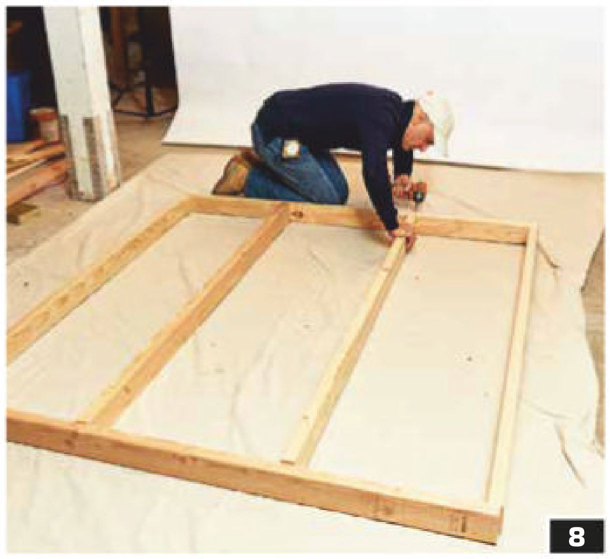
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the back side of each polycarbonate panel. Lay the polycarbonate across the walls, starting in the centre of the wall frame. Make sure all seams align with the centre of a stud, but leave a 3 mm expansion gap between the panels. Fasten the polycarbonate panels to the wall frames with 32 mm decking screws spaced about 405 mm apart.

Slide the polycarbonate panels into place at each end of the wall frame **[10]**, and then use a router fitted with a flush-trim bit to cut away the overhanging polycarbonate **[11]**. A router provides the quickest and most accurate way to trim the polycarbonate, but if you don't own a router, lie the polycarbonate panel in place, mark where it overlaps the wall frame, and then trim it to size using a circular saw or jigsaw.

→ INSTALL FOUNDATION AND WALLS

Set the timber frame foundation on the ground and use a 1.2 m level to confirm that it's level across its width and length. If necessary, dig out or build up the underlying soil until the frame is level. Next, bore 12 mm-diameter holes, spaced about 610 mm apart, through the timber frame. Use a small sledgehammer to pound 12 mm-diameter × 460 mm-long steel reinforcing bars through the holes and into the ground **[12]**. The bars will keep the foundation from shifting. Cover the ground within the timber frame with landscape fabric; then add 80 mm of gravel or bark mulch to create the floor.

Install the prefabricated walls, starting with one of the sidewalls. Stand the wall on the timber frame foundation, aligning the sole plate flush with the outer edge of the 89×140 mm foundation timber **[13]**. Secure the wall to the foundation by driving 75 mm decking screws down through the sole plate and into the 89×140 mm below **[14]**. Space the screws about 610 mm apart. Repeat to install the opposite sidewall.

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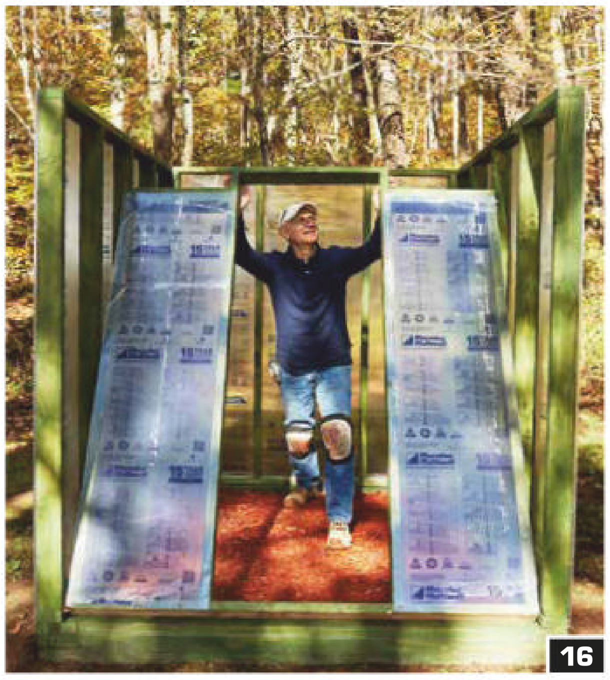

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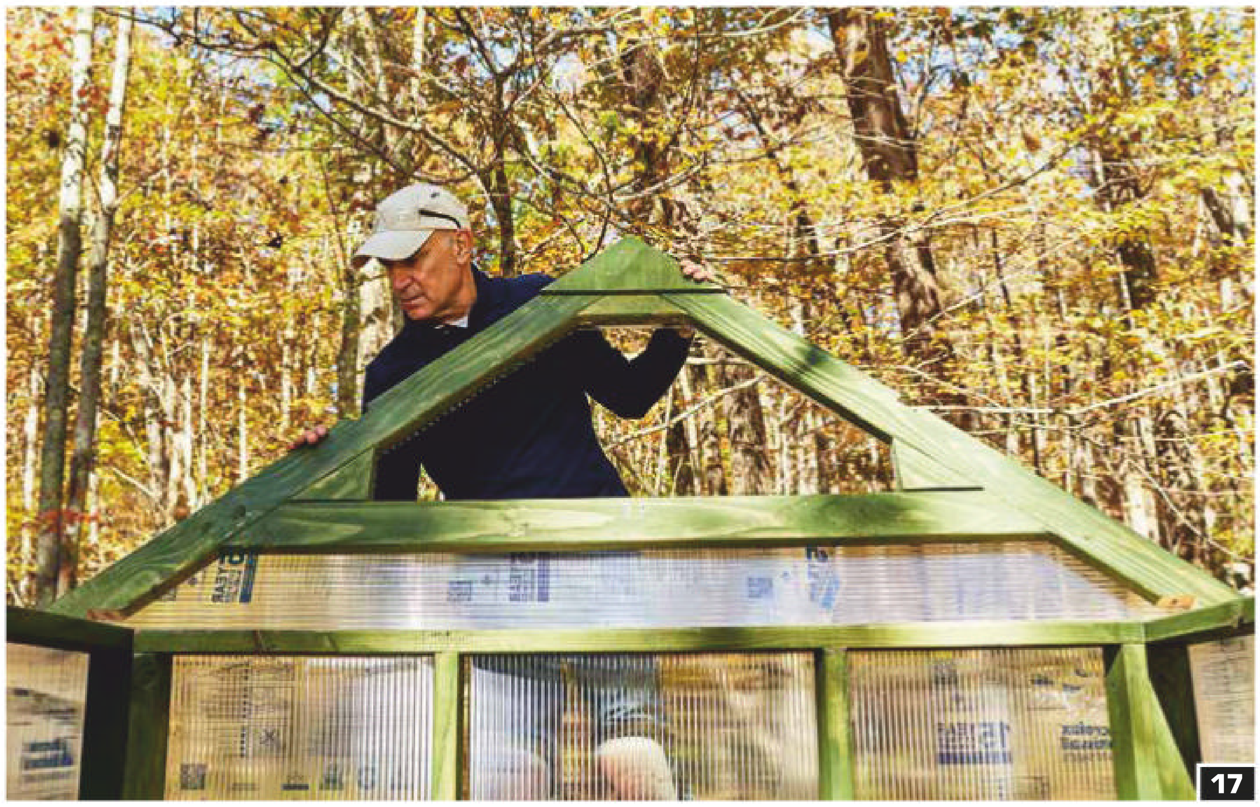
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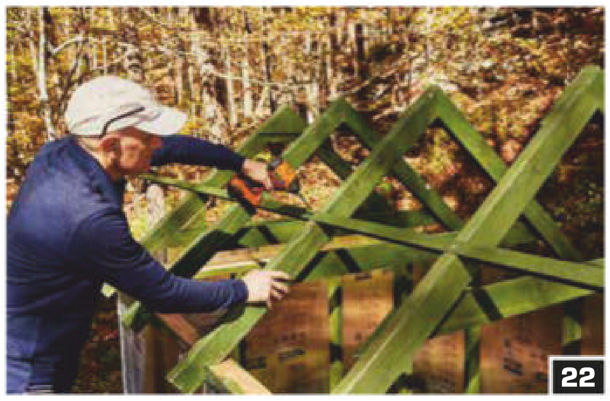
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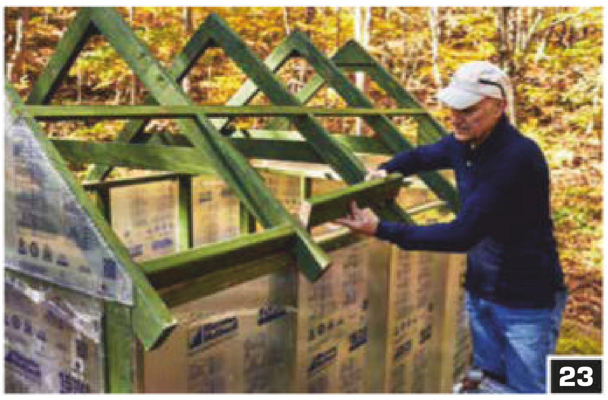
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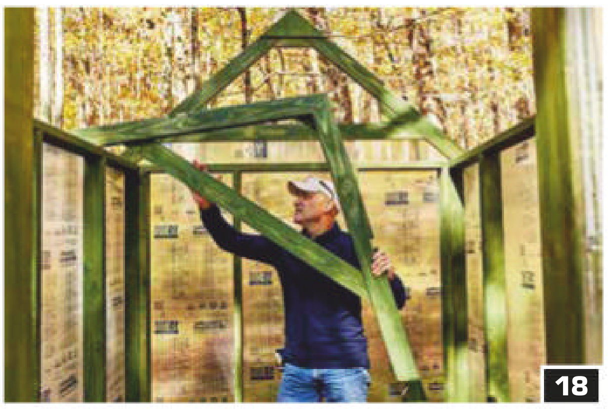
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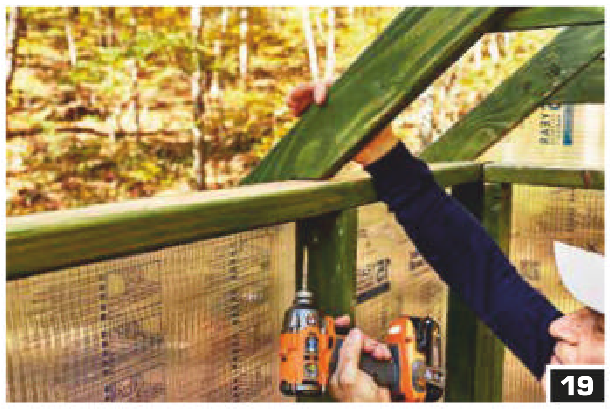
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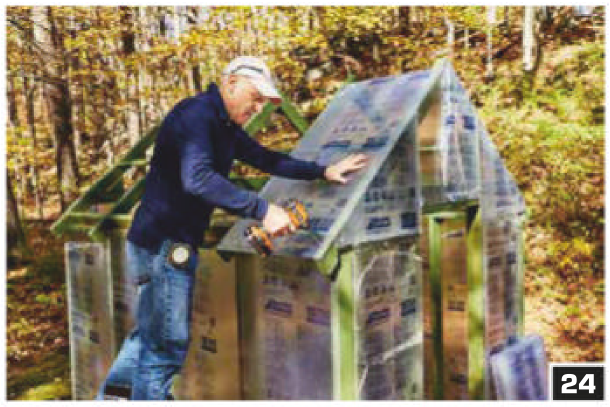
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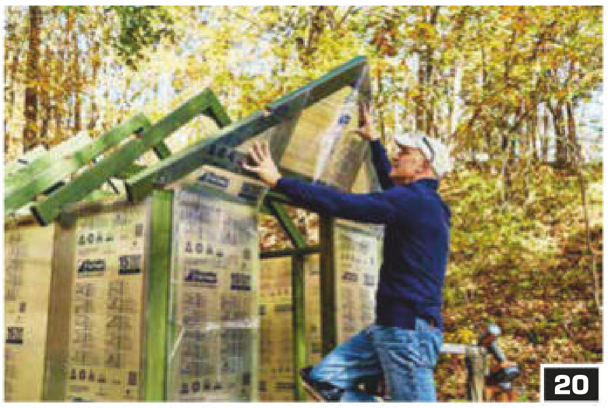
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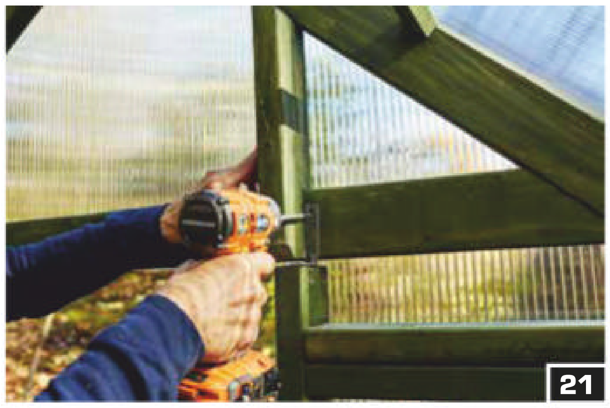
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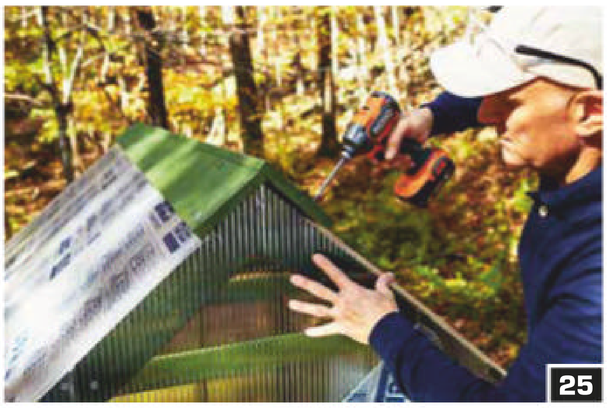
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Raise the rear wall, sliding it between the two sidewalls, and confirm that the walls are plumb. Screw the rear wall down to the foundation with 74 mm drywall screws, and then screw through the studs at each end of the rear wall and into the sidewall [15]; space the screws 405 mm apart. Repeat to install the front wall [16]. Then use a handsaw or reciprocating saw to cut out the 38×89 mm sole plate that runs across the doorway threshold.

→ INSTALL THE TRUSSES

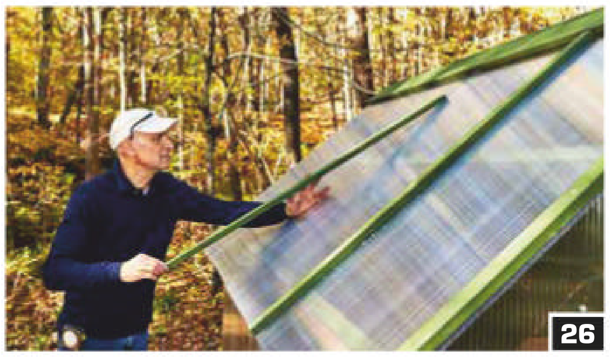
Add the roof trusses by tilting the rear gable-end truss into place on top of the rear wall [17]. Align the truss flush with the outer edge of the wall, and drive a 75 mm decking screw up through the top plate and into the bird's-mouth cut in each rafter. Then install the three intermediate trusses, making sure to position each over a wall stud [18]. Fasten each intermediate truss as you did the gable-end truss: Screw up through the top plate at a slight angle and into the bird's-mouth cut [19].

Set the front gable-end truss on top of the front wall and tilt it into place [20]. Drive 75 mm drywall screws up through the top plate and into each rafter, and then secure the truss with two 75 mm metal L-brackets. Screw the brackets to the top of the trimmer studs and into the 38×89 mm collar tie [21].

→ SHEATHE THE ROOF

Before attaching the polycarbonate roof panels, set a 19×38 mm strap into the notches cut into the top edge of each rafter. Secure the straps by driving a single 40 mm decking screw through the 19×38 mm and into each rafter [22]. Then install a 38×89 mm block between each pair of rafters [23] to close off the space between the top plate and the underside of the polycarbonate roof panels.

Fasten the polycarbonate panels to the rafters with 32 mm decking screws, spaced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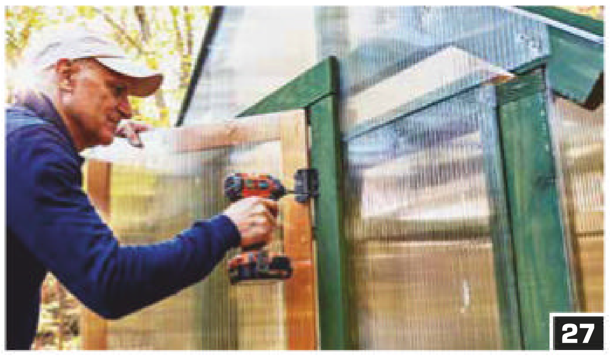
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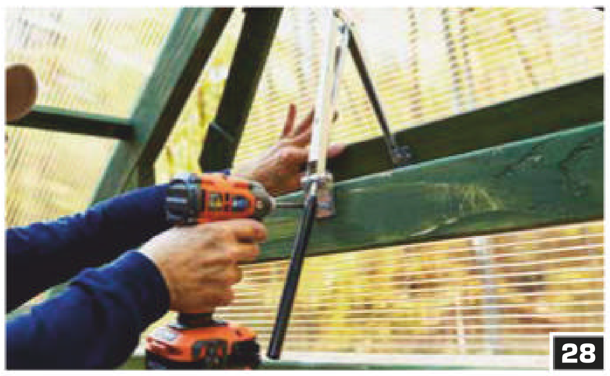
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405 mm apart [24]. Continue installing the panels across the rafters on each side of the roof, leaving a 3 mm gap between each panel.

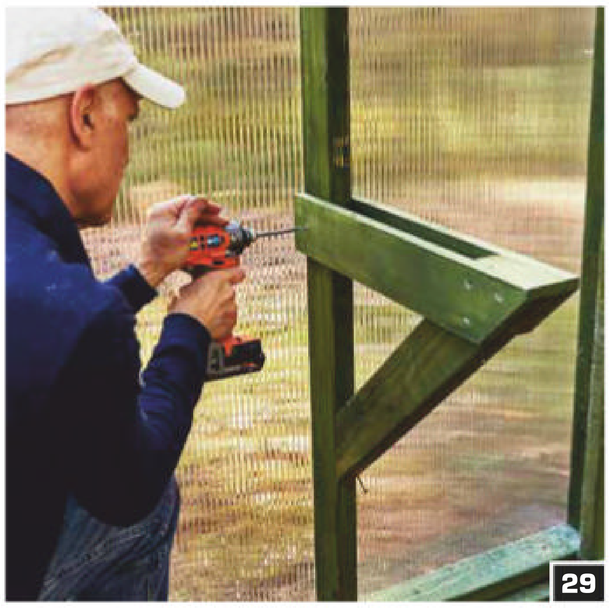
Once all the roof panels are in place, make the ridge cap, using a pressure-treated 19×184 mm and 19×235 mm, each 2 515 mm long. First, use a circular or table saw to rip the 19×235 mm down to 203 mm wide. Then bevel-rip a 10° bevel into one edge of the 19×184 mm. Screw the two boards together and set the ridge cap over the peak of the greenhouse roof. Secure it in place by driving 40 mm decking screws down into the rafters [25].

ADD BATTENS

To help create a weathertight roof, apply a continuous bead of silicone sealant to the seams between the polycarbonate panels. Then cover each seam with a 19×38 mm batten [26]. Fasten the battens with 40 mm trim-head screws, spaced 405 mm apart. Repeat the process to apply battens to the vertical seams in the greenhouse walls.

FINISH THE DOOR AND VENT

Add 19×89 mm exterior casing around the doorway opening, and then hang the door with two self-closing hinges [27]. Mount the hinges 150 mm from the top and bottom of the door. Then install the automatic vent opener by screwing it to the air vent frame and the 38×89 mm collar tie [28].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BUILD THE POTTING BENCH

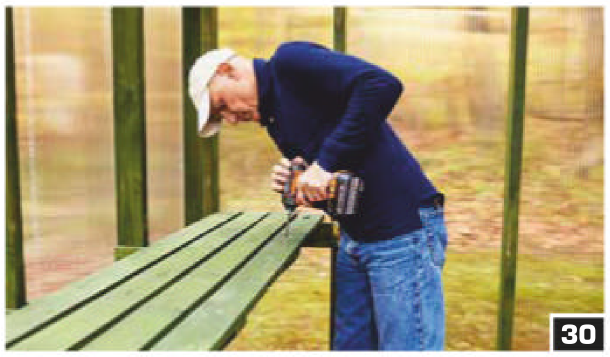
For the potting bench's three mounting brackets, cut two horizontal 540 mm-long 19×89 mm bench supports, and one 654 mm-long 38×89 mm diagonal brace. Trim one end of the six 19×89 mm boards to 45°, and both ends of the three 38×89 mm boards to 45°. Glue and screw one 19×89 mm to each side of the 38×89 mm to create a 45° diagonal brace. (You'll use 40 mm decking screws for the potting bench.) Slip each mounting bracket on to a stud in one sidewall. Position the brackets 895 mm above the timber frame foundation, and fasten them by screwing through the horizontal 19×89 mm and into the side of the wall stud [29]. Then drive a single screw through the lower mitred end of the brace and into the edge of the wall stud.

Since there's no way to attach a mounting bracket to the studs at each end of the sidewall, screw a 19×89 mm cleat across two studs in the front wall and rear wall. Place each cleat at the same height as the mounting brackets: 895 mm above the foundation. These support the 19×89 mm potting bench slats.

Make the surface of the potting bench from four 2 440 mm-long 19×89 mm slats. Set the slats across the mounting brackets and cleats, spaced 13 mm apart, then fasten them with 32 mm decking screws [30].

ADD THE OVERHEAD PLANT HANGER

Complete the interior of the greenhouse by installing an overhead bar for hanging plants and baskets. Cut a length of 12 mm-diameter metal conduit to 2 388 mm. Drill a 12 mm-diameter × 25 mm-deep hole in the 38×89 mm collar tie in the front and rear gable-end trusses. Position the holes 300 mm from the end of the collar ties. Slip the conduit into the holes, and then secure it to the underside of each 19×89 mm collar tie with a single conduit strap [31].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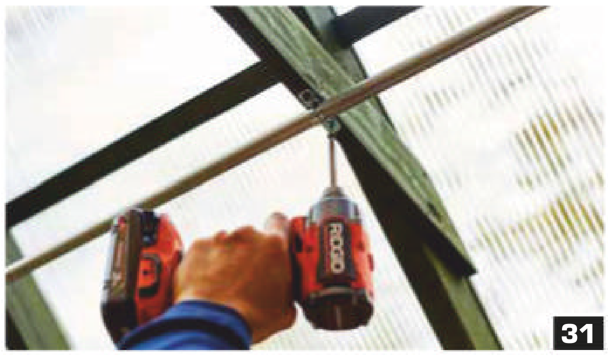
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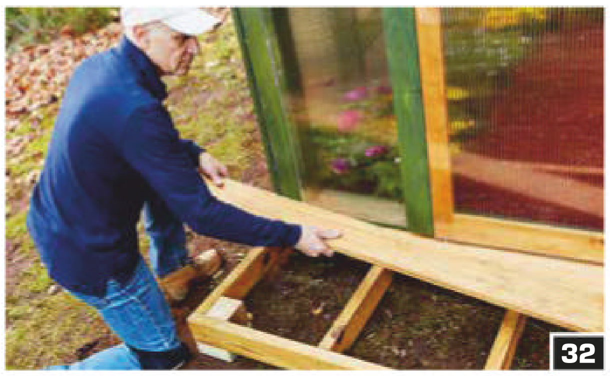
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BUILD AND INSTALL THE PRESSURE-TREATED DECK

For the deck frame, cut two 38×89 mm × 1 830 mm band joists, and five 38×89 mm × 520 mm floor joists. Screw the floor joists between the two band joists with 75 mm galvanised decking screws, spaced 410 mm apart, to create the deck frame. Set the frame in front of the doorway and fasten it to the timber frame foundation with four 90 mm structural screws. Support the outer two corners of the deck frame with concrete blocks or pressure-treated posts to hold the deck level.

Cut four pieces of 22×144 mm pressure-treated decking to 1 830 mm long. Lay the decking across the floor frame, spaced 12 mm apart [32]. Fasten the decking to the deck frame with 50 mm decking screws. Now, with your greenhouse complete, bring in the plants and watch them grow! **PM**

Mazda

CX-5 2.2 L De Akera AWD

FIGURES

» 2.2 L, 4-cylinder, turbodiesel
» 6-speed automatic
» 3-year/unlimited km warranty
» 3-year/unlimited km service plan
» 140 kW; 450 Nm
Price: From R754 000
mazda.co.za

I'VE SAID IT before and I'll say it again – there's something special about the look of all Mazda models in recent years. And the CX-5 is no different. Nothing is out of place – from the bull-nose grille through to the rear fender, it's well balanced, perfectly proportioned, and eye-catching from every angle.

Incredibly, the CX-5 accounts for one-third of the automaker's global sales. It's spacious, stylish, responsive and well-mannered to drive, and these characteristics have been consolidated into a package that's highly popular the world over.

An extensive list of features is included as standard, across the six-model range. There is an auto-dimming rear-view mirror, auto-dimming head-lights, rain-sensing wipers, Isofix child restraint anchor points, privacy glass on the rear-side and back windows, dual-zone climate control, multiple airbags, Apple CarPlay and Android Auto, MZD Connect System, and an eight-inch display, among several other appealing items.

The flagship turbodiesel Akera AT that we had on test adds a 360° camera system, paddle shifters alongside the steering wheel, blind spot monitoring, rear cross-traffic alert, lane departure warning, head-up display, power tailgate, 19-inch black alloy wheels, a Bose sound system, and more.

The lone diesel power plant in the range is light on fuel, responsive, and the vehicle handles nimbly in- and out of town. The torquey diesel takes hills in its stride; floor the pedal and overtaking is achieved easily and safely. The i-stop tech effectively reduces fuel consumption, and lowers emissions on every journey. It's been carefully integrated into the driving experience, ensuring it's unobtrusive.

For its size, space in the cabin is limited, particularly for rear passengers. That said, surfaces and finishes have a premium feel – Mazda certainly knows how to finish a car's interior.

The primary eight-inch display isn't the biggest out there, but it conveys the info you need. It's controlled via a rotating and clickable dial in the centre console behind the gear-select lever, a feature that in my opinion takes some getting used to.

The build quality stands out on the CX-5. This is an attractive all-wheel-drive mid-size SUV that continues to impress with every upgrade.

Floor the pedal and overtaking is achieved easily and safely.

Volkswagen

Taigo R-Line 1.0 TSI

FIGURES

- 1.0 L, 3-cylinder, turbopetrol
- 7-speed automatic
- 3-year/120 000 km warranty
- 3-year/45 000 km service plan
- Petrol: 85 kW; 200 Nm

Base price: From R444 900

R-Line: From R503 000

vw.co.za

VOLKSWAGEN'S NEW TAIGO is a handsome car if ever we've seen one. Exterior aesthetics is certainly something this German carmaker gets right more often than not, and this compact SUV is sure to garner a lot of attention with its sleek curves and well-proportioned profile.

The model we had on test was the range-topping R-Line, featuring stainless-steel pedals, 17-inch Valencia alloy wheels, tinted 'privacy' glass for the rear side windows, and a black headliner. The striking bumper design distinguishes it from the 'Style' and 'Life' spec levels too, which complete the Taigo line-up.

The Taigo is dubbed an 'SUV coupé' by the manufacturer, placed between the T-Cross and the T-Roc in the brand's T SUV model range. (Others here are the Tiguan, Tiguan Allspace, and the Touareg.) In recent times SUVs have been performing better than hatches in new-car sales, which explains why VW has such a comprehensive option list in this sector.

If you're concerned about the performance of the 1.0-litre engine, think again. The three-cylinder turbo-petrol motor develops 85 kW and 200 Nm; it's responsive when you need it to be, zipping easily through urban traffic, and manoeuvrable and swift on the open road, the seven-speed dual-clutch transmission doing exactly what's asked of it in passing scenarios. The light steering action along with the car's compact proportions make this a delightful daily commuter.

The R-Line's cabin has heated front seats, a crisp Beats audio system, sun roof, IQ Drive (including adaptive cruise control, forward collision warning, auto brake, and lane keeping assist), Comfort Package (comprising park assist, keyless entry, and a reverse camera), and an inductive charging tray for compatible smartphones. Interior surfaces, for the most part, have a premium feel, and the central touchscreen hub is intuitive, a trait that's boosted by the inclusion of Apple CarPlay and Android Auto.

Front occupants' space is decent, but people in the rear might struggle for legroom comfort if they're tall, but this is not uncommon in vehicles in this segment. Boot luggage capacity is 440 litres; not cavernous, but adequate for weekend getaways, or a full load of groceries.

We predict the new VW Taigo will carry wide appeal, especially for those who want to stand out from the crowd.

The compact proportions make this a delightful daily commuter.

Land Rover
Discovery D300

FIGURES

» 3.0 L, 6-cylinder, turbodiesel
» 8-speed automatic
» 5-year/100 000 km maintenance plan
» 221 kW; 650 Nm
Price: From R1 896 000
As tested: R1 972 748
landrover.co.za

A FEW MONTHS ago a $2 billion lottery jackpot was won in the United States. It's fun to sometimes ponder outrageous winnings like that, and how I'd spend it, even if it's completely detached from reality.

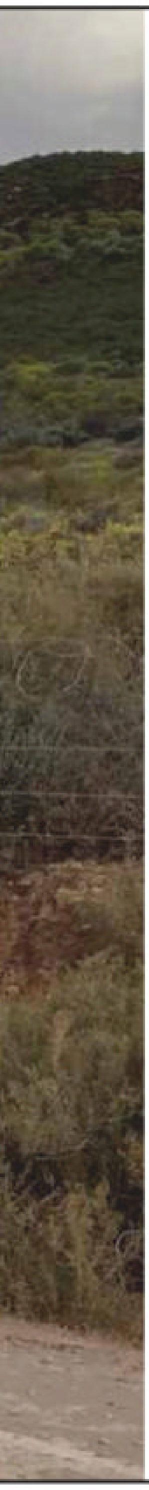
Well, this Discovery would be on my shopping list for my imaginary multi-car garage. In my opinion, it's an impressive addition to a long and proud line of Discovery vehicles. Aside from the obvious eye-catching characteristics and features, what makes it particularly impressive is its 3.0-litre powertrain, an engine with exemplary power and torque, one that propels this mammoth beast with aplomb. The eight-speed automatic transmission mated to the motor delivers smooth and well-timed changes. Drop the throttle in a moment of need, such as a highway overtaking manoeuvre, and you'll be pushed back into your seat as the car is propelled swiftly forwards, quite an enjoyable experience in a vehicle that tips that scales at more than 2 300 kg.

Not everything about this vehicle was to my taste, though, such as the bulbous rear end. It's just not pretty to look at. The off-centred number-plate position doesn't sit well with my perfectionist nature.

Our test model featured enormous 285/40 R23 M+S tyres on chic aluminium wheels with 'Land Rover' branded brake callipers – attractive yes, but not necessarily my first choice for overlanding trips through Namibia or Botswana.

The exterior has bold, powerful lines, a posture that yells 'capable', and, from a practical perspective, roof rails, to which roof racks can be easily added for surf- or SUP boards, or a luggage box, if for some reason you can't fit everything inside the cavernous cargo bay. The lowish front grille has broad air intakes, a honeycomb centre portion, and an almost seamless integration into the long bonnet. Black A and B pillars, black side mirrors, black windows and rear wing, and a high window line, bolster the dapper overall appearance.

The cabin is a tranquil haven, a space where road and other obtrusive exterior noises are kept at bay with highly effective sound deadening. The driver and front passenger's positions have been ergonomically designed; the dash is simple and clean, but don't let that fool you. The 'brain' in this large SUV is vast, with most of its features controlled via the 11.4-inch touchscreen and interactive driver display. Naturally, wireless Apple CarPlay and Android Auto come standard. Other standouts are four-zone climate control, a refrigerated centre console compartment, heated seats in every row (including the third), and a plethora of storage trays, nooks and bins. There's a wireless charging tray with signal booster for your smartphone, numerous USB and 12 V ports, and sophisticated lighting through-



The exterior has bold, powerful lines, a posture that yells 'capable'.

DISCOVERY
KN 94 RT GP

out. The Meridian sound system leaves little to be desired.

A comprehensive quiver of capability features makes this a formidable on- and off-road contender. Highlights are the electronic air suspension (maximum off-road ride height of 283 mm), gradient acceleration control, speed proportional steering, and cornering brake control, and – an optional inclusion on the test unit – the Towing Pack, with Terrain Response 2 and All Terrain Progress Control.

Ride and handling is formidable for a large vehicle – it has a claimed 0–100 km/h sprint time of 6.5 seconds, rather extraordinary for a vehicle of this mass. I found it slightly 'boaty' on winding corners, but it's important to remember this isn't a low-slung performance car. While it's incredibly comfortable on-road, it's on the loose gravel that it really excels.

With the ability to tow a braked trailer up to 3 500 kg, large boats and heavy off-road caravans are in its wheelhouse, making it a solid ally for long family holiday commutes. With all of its options added to the base price of R1 896 000, this vehicle is priced a little less than R2 million, which is why it would take a winning lottery ticket for me to own one. But if you happen to be shopping in this price range, this is a vehicle that should be high on your consideration list. **PM**

TEXT: MARK SAMUEL; PHOTOGRAPHY: MARK SAMUEL, MOTORPRESS, QUICKPIC

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↓ HOW TO BE GOOD AT WHAT YOU DO

/ Khawaja Masood Akthar, 69, CEO of Forward Sports, Sialkot, Pakistan /

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MADE HERE

SIALKOT, PAKISTAN, has been a worldwide hub of football, or soccer ball, production since the late 1800s. British colonials paid local cobblers there to recreate the balls they used at home, and production has never stopped.

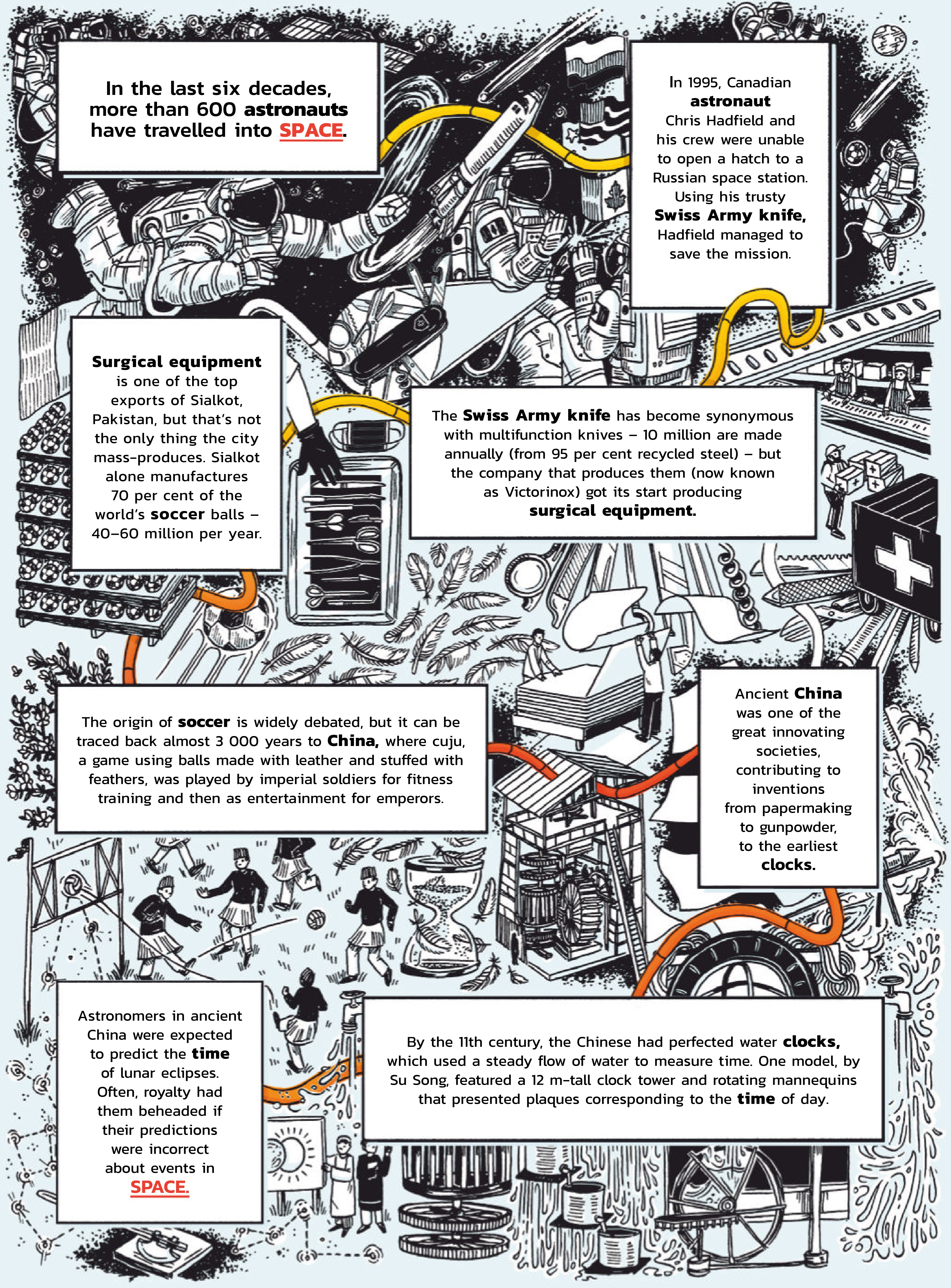
I established Forward Sports in 1991. In our first year, we manually produced 1 000 hand-stitched balls per month. I consider this form most effective – due to the strength of each hand stitch – but I explored new materials, panel shapes, and ways of production. By 2004, we implemented lean manufacturing principles that reduced waste and modernised production with automatic lamination, printing, and panel-cutting machines.

Now, we make hand-stitched, machine-stitched, thermal-bonded, and even airless mini balls (which never deflate), and gradually have grown production to 1 million balls per month. Our clients include Adidas and Diadora, and in 2014 and 2018, we produced the official Fifa World Cup match ball. Through the hardworking staff who have supported me for generations, Forward Sports remains one of the most reputable football manufacturers in the world. **PM**

HOW IT'S DONE

> We cut, press and laminate synthetic leather panels – often 24 or 32, but the count depends on the ball type – then use a polyester-cotton thread to stitch them together, either by hand or by machine. Panels for thermal-bonded balls fuse inside a mould, via an adhesive applied to the panel edges. Next, the panels envelop a bladder made of top-quality rubber from our manufacturing unit in Lahore, Pakistan. We then perform a series of tests, including shooting the ball against metal plates to assess strength, before inspection.

PHOTOGRAPHY: WASIM QADRI/POP MECH VIDEO



In the last six decades, more than 600 **astronauts** have travelled into **SPACE**.

In 1995, Canadian **astronaut** Chris Hadfield and his crew were unable to open a hatch to a Russian space station. Using his trusty **Swiss Army knife,** Hadfield managed to save the mission.

The **Swiss Army knife** has become synonymous with multifunction knives – 10 million are made annually (from 95 per cent recycled steel) – but the company that produces them (now known as Victorinox) got its start producing **surgical equipment.**

Surgical equipment is one of the top exports of Sialkot, Pakistan, but that's not the only thing the city mass-produces. Sialkot alone manufactures 70 per cent of the world's **soccer** balls – 40–60 million per year.

The origin of **soccer** is widely debated, but it can be traced back almost 3 000 years to **China,** where cuju, a game using balls made with leather and stuffed with feathers, was played by imperial soldiers for fitness training and then as entertainment for emperors.

Ancient **China** was one of the great innovating societies, contributing to inventions from papermaking to gunpowder, to the earliest **clocks.**

By the 11th century, the Chinese had perfected water **clocks,** which used a steady flow of water to measure time. One model, by Su Song, featured a 12 m-tall clock tower and rotating mannequins that presented plaques corresponding to the **time** of day.

Astronomers in ancient China were expected to predict the **time** of lunar eclipses. Often, royalty had them beheaded if their predictions were incorrect about events in **SPACE.**

ILLUSTRATION: LUCY ENGELMAN

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